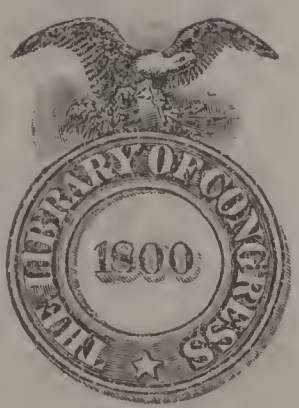

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Practical Automobile Instruction

A Complete Cyclopedia of Practical Information for Garage Men, Chauffeurs, Repair Men and Automobile Designers and Engineers

with

Special Reference to Carburetion, Ignition, Starting and Lighting, Motor Troubles and Repairs, Machine Shop Practice, Oxy - Acetylene Welding and Cutting and Carbon Removal by the Oxygen Process

by

L. ELLIOTT BROOKES

and

HAROLD P. MANLY

FULLY ILLUSTRATED

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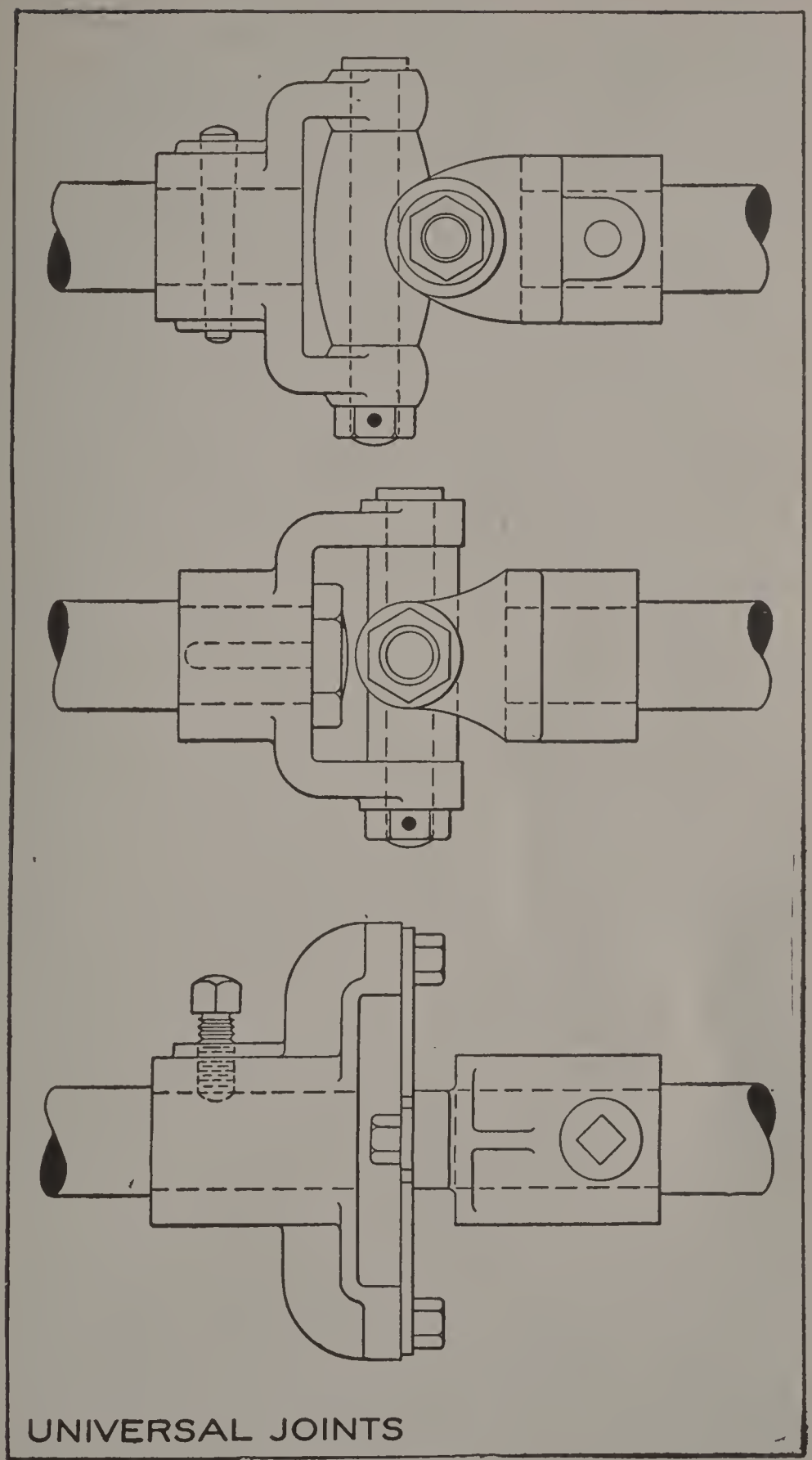


Fig. 228

Joints, Knuckle. Swivel or knuckle-joints for connecting the steering arm of the wheel, or lever steering mechanism to the arms on the knuckle-joints of the steering wheels are of various forms. Figures 225 and 227 show knuckle-joints which may be used for the above purpose. They are of simple construction and practically inexpensive to make. They may be used with any standard drop-forged jaw-ends.

Joint—Universal. The elementary form of a universal-joint or flexible coupling consists of a spiral spring. Such a form of universal-joint is sometimes used to drive a rotary pump, or a small generator on a car. The rear wheels or axle of a car are sometimes driven by means of a longitudinal shaft with a quarter-turn drive on a counter shaft, or a bevel gear drive attached to the differential gear of the rear axle. In such cases some form of universal-joint is necessary to allow the rear wheels and axle to accommodate themselves to the inequalities of the road surface. Three forms of universal-joints are shown in Figure 228. The upper view in the drawings shows the form most generally used on motor-cars, for the purposes just described. The one shown in the center view will allow a greater amount of angular distortion than the form shown in the upper view, but is of a more expensive construction. Where only a slight amount of angular distortion is needed, the construction shown in the lower figure in the drawing is very suitable, the two jaws or

knuckles of the joint being flexibly attached by means of a plate of spring steel.

A form of universal joint, or flexible coupling, of recent introduction, is that making use of leather or other flexible material securely fastened to two forked members in such a way that with the members placed at an angle to each other, power is delivered from one to the other through the flexible material that is fastened to both of them.

Large powers are transmitted in this way by using a ring of heavy material similar to tire fabric and fastening the couplings of the two shafts to this ring at alternate positions by secure fastenings and bolts. The difference in alignment is taken care of by the ring of flexible material, and it has been found that this form of drive is quite free from trouble, and, of course, requires neither lubrication or covering against dust and dirt.

Kerosene as a Fuel. Kerosene has been used as an explosive power, and crude petroleum is gaining favor as an efficient liquid fuel. With a specific gravity varying from 0.78 to 0.82, and a vapor flashing point at 120 to 125 degrees Fahr., kerosene ignites at 135 degrees Fahr., and boils at 400 degrees Fahr. Its vapor is five times heavier than air, and requires 76 cubic feet of air to one cubic foot of vapor for its combustion, giving 22,000 heat units per pound, or 4,000 more than gasoline.

KEROSENE AS A CLEANSING AGENT. Kerosene

injected into a motor cylinder and allowed to remain over night will remove all deposit from the piston head. It should then be blown out through the relief-cock or the exhaust-valve.

Knight Engine. See *Engine, Knight.*

Knocking—Locating Cause of. Tracing a knock is sometimes a puzzling job. It may be in one of the main bearings of the engine, in the camshaft bearings, in a loose valve lifter, in a loose camshaft gear key, in a loose pump or magneto drive coupling, an unsuspected loose bolt between two parts supposed to be fast, or in any of a dozen, or score of other unsuspected places. A valuable aid in locating a mysterious knock is a flexible speaking tube such as is used with phonographs. One end of such a tube can be held to the ear and the other moved about from point to point until the exact spot is found where the noise is loudest. Another aid is a light bar of iron, one end of which is pressed against the part where the knock is suspected and the other touched to the forehead or the teeth, when the sound is clearly transmitted.

Knocking or pounding is an inevitable warning that something is wrong with a motor. It may be due to any of the following causes:

Premature ignition: The sound produced by premature ignition may be described as a deep, heavy pound.

Using a poor grade of lubricating oil will cause premature ignition. The carbon from the

oil will deposit on the head of the piston in cakes and lumps, and will not only increase the compression, but will get hot after running a short time and will ignite the charge too early, and thereby produce the same effect as advancing the spark too much. If this is the cause the pounding will cease as soon as the carbon deposit is removed from the combustion chamber.

Badly worn or broken piston-rings.

Improper valve seating.

A badly worn piston.

Piston striking some projecting point in the combustion chamber.

A loose wrist-pin in the piston.

A loose journal-box cap or lock-nut.

A broken spoke or web in the flywheel.

Flywheel loose on its shaft.

If the spark plug be placed so as to be exactly in the center of the combustion space, an objectionable knock occurs, which has never been fully explained. In some motors it renders a particular position of the spark control lever unusable; this form of knock disappears either on making a slight advance or retardation of the ignition.

Explosions occurring during the exhaust or admission stroke. This is almost always due to a previous misfire, and it is prevented by stopping the misfires.

If the ignition is so timed that the gases reach their full explosion pressure during the compression stroke, that is, if the spark be unduly

advanced when the motor is not running at a high speed, an ugly knock occurs, and great pressure is developed on the crank-pin bearing, wrist-pin, and connecting rod. The result may be the bending or distorting of the rod.

The crank-pin may not be at right angles to the connecting rod.

The bearings at either end of the connecting rod may be loose. A knock during the explosion stroke, and also at each reversal of the direction of the piston.

If the crank shaft is not perfectly at right angles to the connecting rod, the crank shaft and flywheel will travel sideways so as to strike the crank shaft bearings on one side or the other.

Lamps, Electric. The small incandescent lamps used for automobile lighting are almost invariably of the tungsten filament variety. Two types are in use, considered from the bulb standpoint, one of which exhausts the air from the bulb until a high degree of vacuum is secured, and the other one of which replaces the air with the inert gas, nitrogen. One is called the vacuum bulb and the other the nitrogen bulb. Two types of bulb base are in use, the single contact, in which one side of the circuit is secured through metal of the base, and the double contact with two insulated leads. Lamp bulbs vary in diameter from ¾ to 2-1/16 inches.

Lighting, see *Starting and Lighting Systems*

Lubrication. To ensure easy running, and reduce the element of friction to a minimum it is absolutely necessary that all surfaces rubbing together should be supplied with oil or lubricating grease, but it is also a fact, not so well understood, that different kinds of lubricant are necessary to the different parts or mechanisms of a motor car.

As the cylinder of an explosive motor operates under a far higher temperature than is possible in a steam engine, consequently the oil intended for use in the motor cylinders must be of such quality that the point at which it will burn or carbonize from heat is as high as possible.

While a number of animal and vegetable oils have a flashing point, and yield a fire test sufficiently high to come within the above requirements, they all contain acids or other substances which have a harmful effect on the metal surfaces it is intended to lubricate.

Lubricating Oils. The qualities essential in a lubricating oil for use in motor cylinders include a flashing point of not less than 500 degrees Fahrenheit, and fire test of at least 600 degrees, together with a specific gravity of 25.8.

At 350 to 400 degrees Fahrenheit, lubricating oils are as fluid as kerosene, therefore the adjustment of the feed should be made when the lubricator and its contents are at their normal heat, which depends on its location in the car. Steam engine oils are unsuitable for the dry

heat of motor cylinders in which they are decomposed whilst the tar is deposited.

All oils will carbonize at 500 to 600 degrees Fahrenheit, but graphite is not affected by over 2,000 degrees Fahrenheit, which is the approximate temperature of the burning gases in an explosive motor. The cylinder of these motors may attain an average temperature of 300 to 400 degrees Fahrenheit. So that graphite would be very useful if it could be introduced into the motor cylinder without danger of clogging the valves, and could be fed uniformly. These difficulties have not yet been overcome. Graphite is chiefly useful for plain-bearings and chains.

The film of oil between a shaft and its bearing is under a pressure corresponding to the load on the bearing, and is drawn in against that pressure by the shaft. It might not be thought possible that the velocity of the shaft and the adhesion of the oil to the shaft could produce a sufficient pressure to support a heavy load, but the fact may be verified by drilling a hole in the bearing and attaching a pressure gauge.

Roller and ball-bearings provide spaces, in which, if the oil used contains any element of an oxidizing or gumming nature, a deposit or an adhesive film forms upon the sides of the chamber, the rollers or balls, and the axle. This deposit will add to the friction, hence it is the

more important to use a good oil, or a petroleum jelly in such bearings.

Air-cooled motors, being hotter than water-cooled, must have a different lubricant, or one capable of withstanding higher temperatures.

The effect upon animal or vegetable oils of such heat would be to partially decompose the oils into stearic acids and oleic acid and the conversion of these into pitch. Such oils are therefore inadmissible for air-cooled motor use.

Mineral oils are not so readily decomposed by heat, but at their boiling points they are converted into gas, and any oil, the boiling point of which is in the neighborhood of the working temperature of the motor cylinder, is useless, as its body is too greatly reduced to leave an effective working film of oil between the cylinder and the motor piston.

The essentials for the proper lubrication of air-cooled motors are:

That the oil should not decompose.

That it should not volatilize, as this will result in carbon deposits.

That its viscosity should be equal to that of a good steam engine oil at similar temperatures.

That it should be fluid enough to permit of its easy introduction into the cylinder.

That it will have no corrosive effect on the cylinders and no tendency to gum.

That it will not oxidize with exposure to air and light.

Lubricating Devices. Some makers of verti-

cal cylinder motors use the splash system, whereby oil fed by gravity from a tank above the level of the crank-case flows into the crank-case, whence it is splashed over the piston and the wrist and crank-shaft bearings. The large end of the connecting rod, which works in the crank-case, is made to dip or splash into a bath of oil. This lubricates the crank-pin. The splashing is invariably utilized to lubricate the cylinder by wetting the bottom of the piston

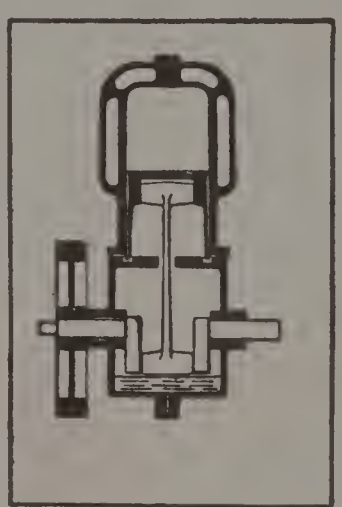


Fig. 229

and splashing into the cylinder. A little ring is sometimes made in the crank-case, into which the oil collects and into which also the end of the piston dips.

Fig. 229 shows a vertical cylinder motor using splash lubrication.

The various methods of oiling outlined under *Lubrication Systems* should be noted, inasmuch as they give the principles by which any system may be classified. Practically all applications are modifications of one or the other.

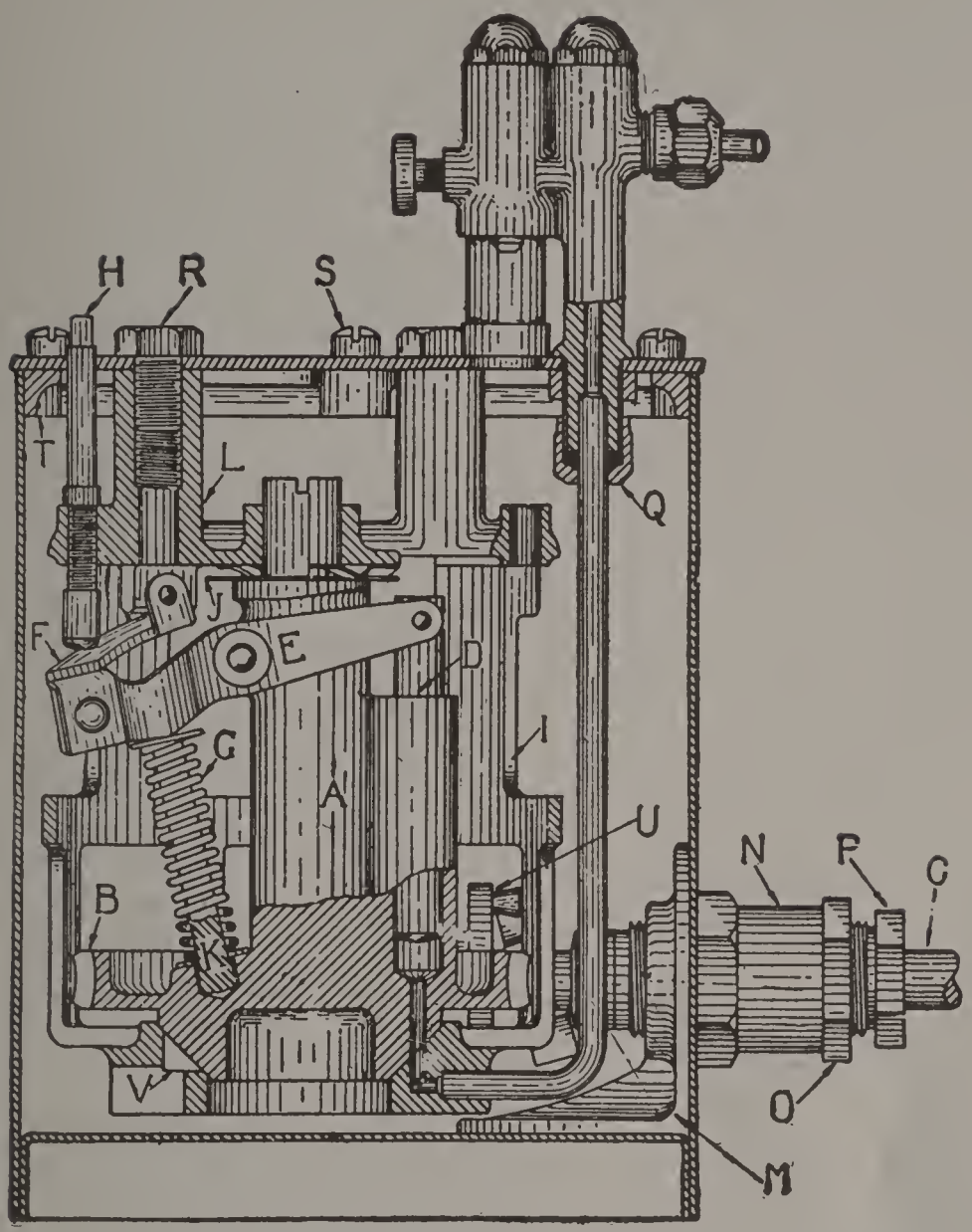


Fig. 230

McCord Mechanical Oiler. A, Center Post. B, Worm Wheel. C, Drive Shaft. D, Plunger. E, Yoke. F, Cam. G, Plunger Spring. H, Adjusting Screw. I, Basket. J, Center Post Spring. K, Spring Guide. L, Spider. M, Stuffing Pad. N, Stuffing Box. O, Gland Lock Nut. P, Stuffing Gland. Q, Bleeder Nut. R, Spider Lid Screw. S, Lid Screw. T, Lid Frame. U, Safety Ratchet. V, Oil Inlet Port.

The number of feeds used varies on the different cars from two to fourteen, depending upon the number of cylinders and bearings used on the engine. In a six-cylinder car, it is usual to find four feeds going to the crankshaft bearings, six to the cylinders, three to the crankcase, and one to the fan bearing.

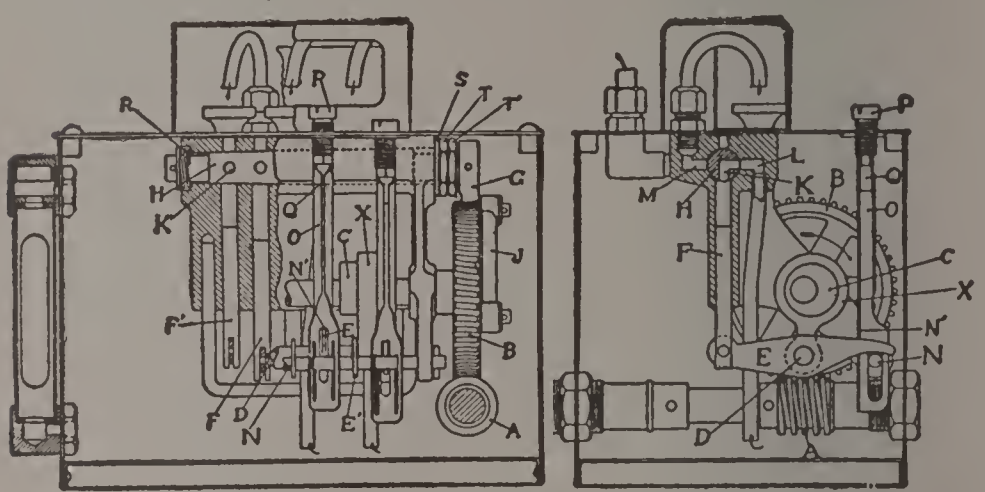


Fig. 231
Hancock Mechanical Oiler

When mechanical oilers are used for lubricating the motor, the crank-case is usually divided into partitions, most of them dividing it into halves, one compartment for the two front cylinders and the other for the two rear cylinders. Sometimes three partitions, giving four compartments, are used. This arrangement gives one portion for each connecting rod. When this construction is used, the center partition will be found higher than the other two.

A force feed lubricator usually consists of an oil tank through which passes a shaft, which has a slow, but constant motion through me-

chanical connection with the engine. This shaft successively operates by means of cams, or otherwise, a series of small piston pumps, usually submerged in the oil, each pump feeding an oil tube. The piston displacement of each pump may be adjusted independently by changing the length of stroke so that any amount of oil desired may be delivered. Each pump stroke corresponds with a definite number of engine strokes.

In some systems of force feed lubrication the oilers are made without valves, double plungers being used to force oil to the sight feeds, and drawing positively from the sight feed and forcing to the delivery points.

The Hancock lubricator, Fig. 231, is of this type, and action is as follows: Worm A drives worm gear B and the shaft to which it is attached. On this shaft are two eccentrics C which impart a reciprocating motion to rod D carrying rocker arms E, and E′. To one end of these arms are fastened pistons F, and F′. The crank G is secured to the taper shaft H, and through connecting rod J a rocking motion is transmitted. This taper shaft H is provided with holes K, which on the suction stroke register with the openings L, and L′, and the pistons, and on the forcing stroke with openings M, M, and the pistons. The arrows indicate the direction of flow of the oil to delivery points, the quantity being regulated by controlling the stroke of piston F through the lost

motion allowed between the stop rod L and regulating piece O. P is the regulating screw, provided with a projection Q, which fits firmly into the upper end of piece O, forming a positive locking device. Shaft H is equipped at one end with a spring R which holds it to its seat.

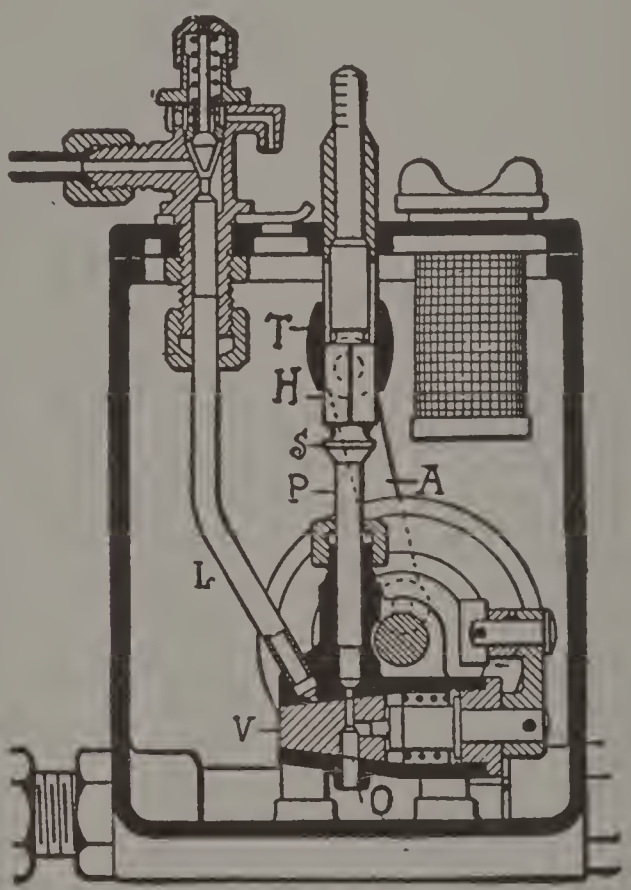


Fig. 232
Lavigne Oiler

At the other end, washer S and two lock-nuts T and T′ hold the shaft in its correct position. The shaft is thus allowed to run free in its gear, requiring but little power. Any number of feeds from one to sixteen may be used to work against pressure. In the Lavigne mechanical oiler, Fig. 232, the pumps are without check

valves, or springs of any kind. The plungers P, are raised and lowered by arms A attached to the drive shaft. On the up stroke a certain quantity of oil is drawn into each pump cylinder, and on the down stroke this quantity is discharged.

At the base of each plunger is an oscillating valve V, which, as illustrated, has the opening O ready for the up stroke, so that oil may be drawn from the reservoir into the plunger. Before the down stroke begins, the valve is oscillated by a cam device so that the entrance O is closed and the oil is directed through the lead L, which connects with the bearings. There is a time when the plunger L, is stationary at the top, and also at the bottom of the stroke, which is achieved by the cross head H, which raises and lowers the plunger. This cross head slides on the plunger until it contacts with a lower shoulder S and an upper one T. And during the period of no movement of the plunger the valve V is being oscillated to be ready to open the entrance O for intake stroke, and another passage for the expulsion stroke.

The Pierce-Arrow oiling system, Fig. **233,** is partly positive, and partly gravity. The oil pump is positively driven from the engine, and pumps the oil from the crank chamber up into the reservoir located on the engine. Pipes lead from this reservoir to every crankshaft bearing, the flow to the bearings being by gravity under a head of twelve inches, which corre-

sponds to a pressure of about six ounces. The crankshaft bearings are drilled hollow, and in this way the crankpins and large ends of the connecting rods are lubricated. A gauge is usually placed on the dash to indicate the quantity of oil in the reservoir.

The Pierce system does not allow any oil to remain in the crankcase, the oil flying off the

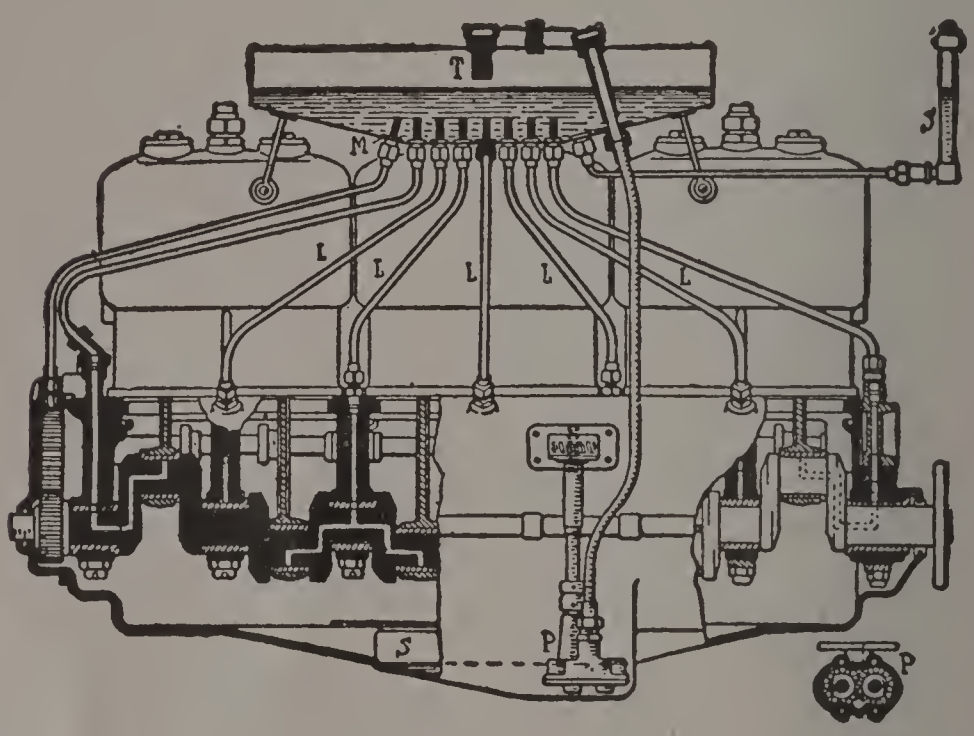


Fig. 233
Pierce-Arrow Oiling System

crankpins being sufficient to lubricate the cylinders. As there is always a mist of oil flying around in the crankcase, it is known as the "mist" system.

As shown in Fig. 233 the oil supply is carried in a sump S beneath the crankcase, and the crankcase bottom is sloped towards the center so that oil falling in it is immediately

drained into the sump. The gear pump P, driven from the camshaft through a vertical shaft, elevates the oil to a tank T carried above the cylinder heads, and from this a lead L passes direct to each of the crankshaft bearings. From these bearings the oil passes through the drilled crankshaft to the lower bearings of the connecting rods, whence any overflow falls into the crankcase, or is thrown into the cylinders in the form of a mist through the slot in the baffle plate, closing the lower end of the cylinder to prevent an excess of oil getting on the walls. This mist not only cares for the cylinder walls, but also oils the wrist-pin bearing. The flow of the oil through the leads L from the tank to the bearings is regulated by thimbles M, inserted in the upper ends of the leads where they enter the oil tank, and in each thimble is a small opening which allows only a limited amount of oil to flow. The size of the openings in the thimbles is varied to suit the demand of the bearings for oil.

Flywheel Oiling Systems. In the Ford flywheel system of oiling illustrated in Fig. 234, the flywheel casing serves as an oil reservoir, and the rotation of the wheel throws the oil up into pockets, from whence it is conducted through pipes to the crank-case. The angle of the pipes is such that even on extreme grades there is sufficient drop to insure a flow of oil. A depression M is found in the crank case beneath each connecting rod, in order to limit

the amount of oil carried in the crankcase, and also to insure an even level of oil within the case.

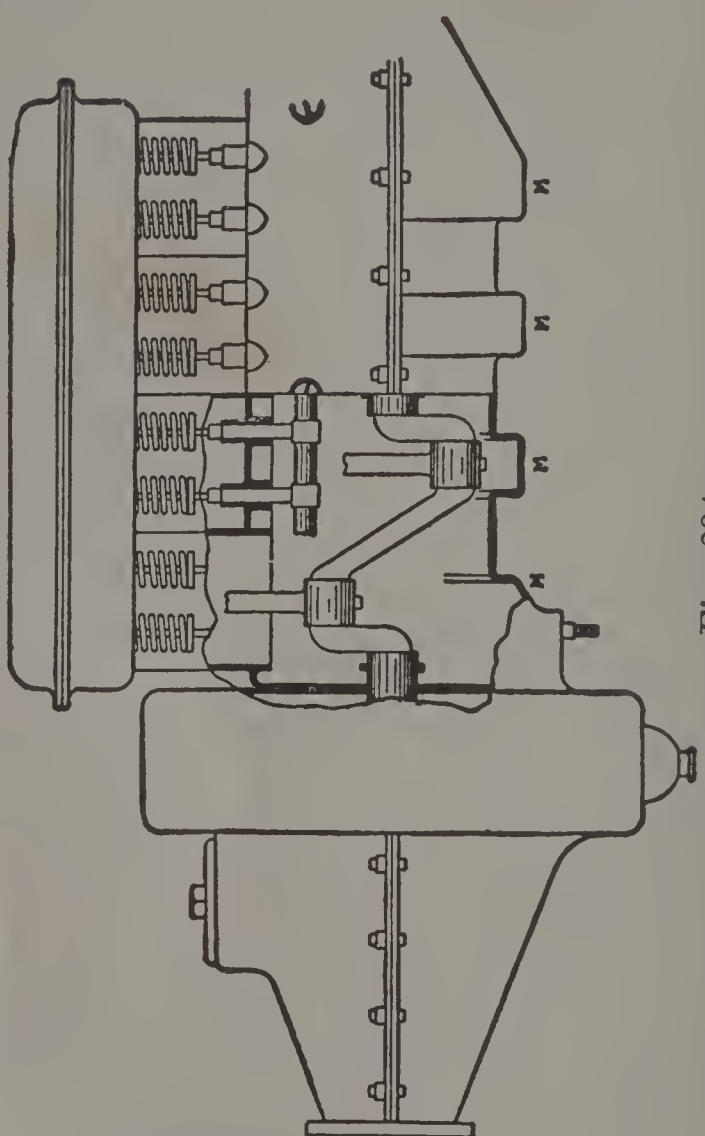


Fig. 234
Ford Flywheel Oiling System

Drilling Oil Passages in the Crank Shaft. Figs. 235 and 236 show two different methods of drilling the crankshaft to convey the oil to

the crankpins, and it will be noticed that the oil holes discharge at the highest point of the revolution, corresponding to the position of the piston at the beginning of the power or firing stroke. The supply is received by the main bearings from the oil pump and the oil hole in the shaft, coinciding with that from the oiler has a little oil forced in each revolution and, generating centrifugal force throws it rapidly through the passages. The majority of modern motors are equipped with splash lubrication and have the connecting rods dip into the oil

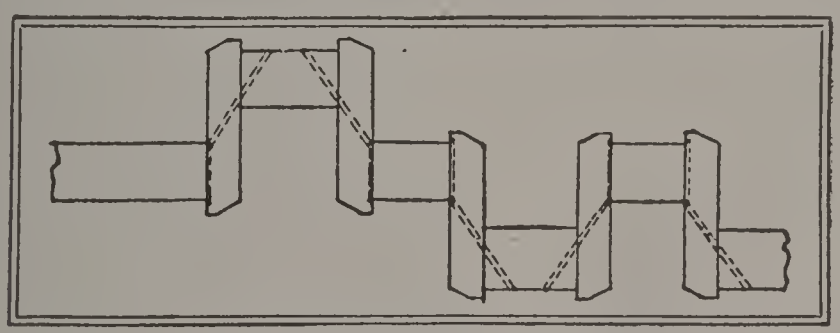


Fig. 235

each revolution and splash it all over the inside of the crankcase. Some types are equipped with a scoop pointing in the direction of rotation, at the lower end of a passage connecting with the crank pin. The oil is sent into these passages with considerable force, owing to speed of rotation, thus assuring sufficient oil to the connecting rod bearings.

This is worked to the ends of the bearing and thrown off in the shape of a fine mist that penetrates to every part of the crankcase. The oil splashed onto the lower cylinder walls and not

carried up by the piston is caught in little troughs, cast in the crankcase and drilled so that the oil runs down to the main bearings. In addition to the pipe from the oiler, the better designs provide an oil wick, or an oil ring or chain, all types carrying oil from a shallow pocket corded in the bearing cap, the wick by capillary attraction, and the ring or chain, revolving with the shaft, their lower ends immersed in the oil will carry up a considerable quantity that will spread over the shaft. This

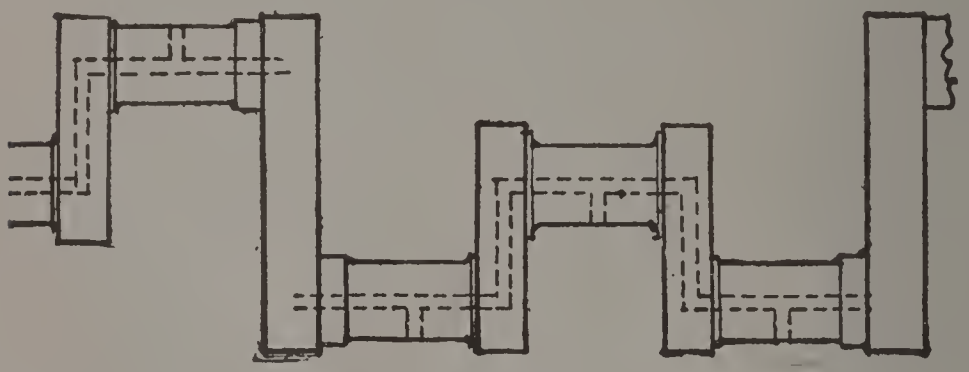


Fig. 236

oil ring system is used very successfully in electrical machinery. With a splash lubrication it is advisable to drain the crankcase at frequent intervals, and also to put in a fresh supply of oil.

Care should be exercised to select heavy oil for air-cooled engines or old engines, and a comparatively light oil for new cars.

Cylinder Oil Testing. There are really two parts to the fire test, as it is called. One is the test for flash point. This may be determined

as follows: Take two pieces of glass of the same size, and large enough to cover a small glass beaker. In one of them cut a couple of notches. These are for two purposes. One is for the thermometer and the other for the flash point determination. Insert a thermometer in the beaker, filled with the oil under test. Place the notched glass over this and the other piece of glass over that, taking care to cover the notch not in use. Now uncover this notch, note the temperature, and apply a lighted match to the opening. If nothing results, warm the oil slowly over a flame to a higher temperature and take another trial and reading. Continue the test until upon the application of the lighted match the oil vapor over the oil flashes. The thermometer reading at that point gives the flash point. The glass plates may now be removed, and heating continued. The match is applied at similar intervals, until finally the oil burns, which will usually occur at about 50 degrees above the flash point.

An additional test is for precipitation at a known temperature. This is also made in a beaker. Two ounces is the usual amount. It is heated to the desired temperature, at which the oil may change color, but must not show a precipitation. Still another good oil test is the evaporation test. This is the result of slow heating, and the usual specification is that the oil shall not lose over 5 per cent. of its volume when heated to 150 degrees Fahr. for 12 hours.

Lubricating Systems:

Full Force Feed. Oil is forced by pump pressure to the main bearings and, by means of drilled holes in crank webs, to crank pins and through hollow connecting rods, or oil pipes attached thereto, to the wrist pins. Oil returns to sump, or reservoir, and is circulated again.

Force Feed. Oil is forced by pump pressure, or the centrifugal force of the revolving flywheel, to main bearings and through drilled holes in crank webs to crank pins. The wrist pins and cylinder are supplied by oil thrown from connecting rods. The connecting rods do not dip. Oil returns to sump, or reservoir, and is circulated again.

Force Feed and Splash. Oil is forced by pump pressure, or the centrifugal force of the revolving flywheel, to the main bearings and through drilled holes in the crank webs, to crank pins. The oil from the main bearings falls to wells in the bottom of the crank case, or to adjustable troughs, into which the connecting rods dip and splash oil to all parts of the engine.

Splash. A constant level is maintained in the crank case by an overflow to the sump, or reservoir, below, whence the oil is circulated again.

Lubrication of Gears and Clutches. The modern ball-bearing gear box requires but little attention. Periodic filling with suitable lubricants is sufficient. On chain-driven cars the gears and differential are usually exposed by lifting one cover. On shaft-driven cars the

differential and rear axle system requires a certain amount of attention, as too much oil in the differential is liable to leak through the axle sleeve and hub, usually getting on the brake drums. If this happens, the best thing to do is to jack the wheel up and squirt gasoline on the drum, slowly revolving it meanwhile. Manufacturers usually put a plug in the differential case showing the proper height at which to keep the oil level. The gear box should be kept a little less than half full. If too much is put in, the oil will be thrown out of the shaft and bearing housings, but a little leakage does no harm as there is always dust present and the oil leaking will serve to fill the crevices and make the case dust-tight. In regard to the wheels, universal joints, clutch, and many little places about the car, all need attention occasionally as almost any motor car driver knows.

The wheels should be cleaned and packed with grease once or twice a season, universal joints at intervals necessarily shorter. Latest designs provide for their lubrication through the shaft from the gear box. Earlier types are best packed in grease and enclosed in a leather boot. On many shaft-driven cars, where the shaft runs through a sleeve, daily attention should be given. The lack of a few drops of oil may rob the car of 50 per cent of its power. Multiple disc clutches use oil, or an oil and kerosene mixture, and the tendency seems to be

for the oil to gum. Their action when slipping or dragging is sufficient indication as to when they are in need of attention. Leather-faced clutches will work much better when cleaned with kerosene and given a dose of neatsfoot or castor oil. The oil should be spread over the surface of the leather by using a long knife blade, or by running the motor for a few moments with the clutch released. When treating the clutch leather this way it is better to let it stand over night if possible, and with the emergency brake lever, or a block of wood against the pedal hold the clutch disengaged. A hand oil can with a long spout is almost indispensable, and the starting crank, the steering pivots and connections, and the spark and throttle connections, gear control and emergency brake levers, clutch and brake pedals, shafts and connections and the fan bearings will all work much quieter and sweeter for a few drops of oil regularly. It is the practice of drivers to fill the oil can from the cylinder oil supply and this practice is to be commended, as many lower grade oils contain acids enough to etch steel.

Gear Case and Rear Axle. It is a familiar fact that the gear case requires to be periodically emptied of oil, and the accumulated metal grit washed out before fresh oil is supplied. The same is true of the rear live axle casing, except that the gears in the axle do not clash and therefore do not wear out as fast as the change

speed gears. At least once in a season the oil in the rear axle should be drained out, a liberal supply of kerosene introduced, and the axle jacked up while the engine is run to agitate the oil and wash out the differential, etc.

Magnetic Gear Shift. The electric gear shift may be said to consist of two units, the "shifting assembly," or group of magnets attached to the transmission case, and the "selector-switch," or push-button group, located on the top of the steering column. The electrical current required to energize the magnets is derived from a storage battery, Fig. 237, ordinarily supplied as part of the starting and lighting systems on all cars.

The selector-switch is made up of a number of buttons, one for each speed, and one for the "neutral" which has not electrical connection. There is also a button for operating the horn. These buttons are provided with arched, laminated contacts of copper, backed up with a steel spring and insulated from the button proper. The top of the switch carries a locking-plate for locking any button which may be depressed and also carries an interlock, which makes it impossible to press down more than one button at a time. At the bottom is a hard rubber base, which carries a copper contact for each button and a contact common to all speeds. It also serves as a base for the return spring provided for each button.

The wiring, Fig. 238, consists of a lead passing from each coil through a terminal block to

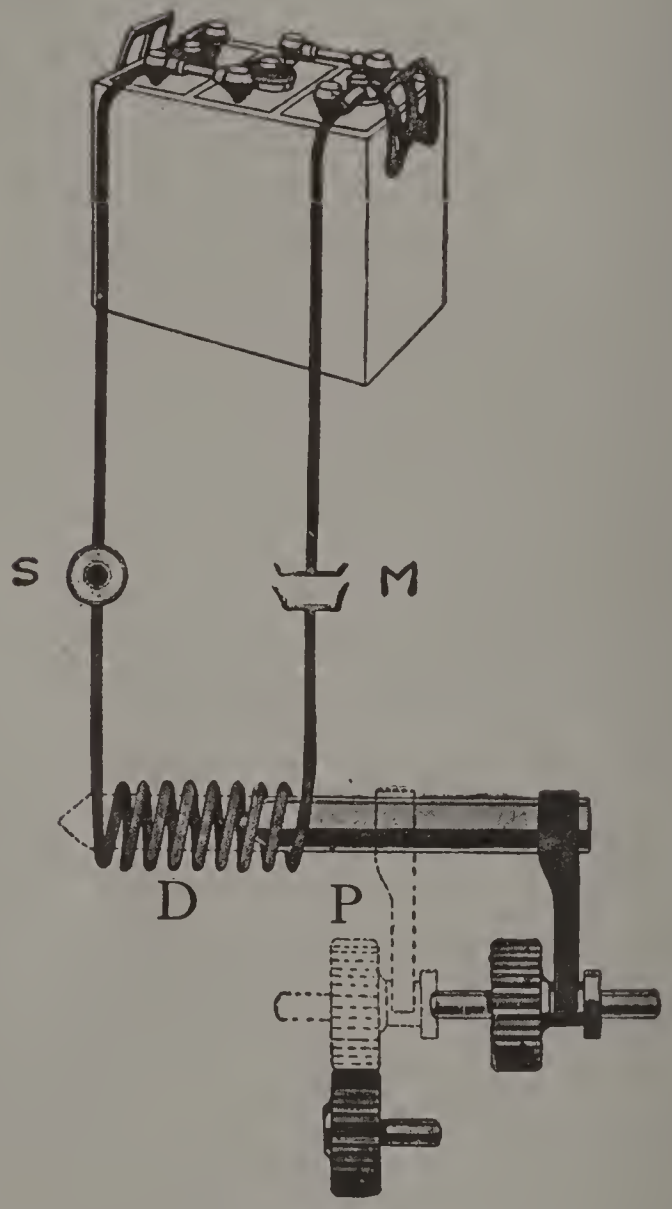


Fig. 237
Action of the Magnetic Gear Shift

its particular speed button on the selector-switch, while the other lead from the coil is joined to a neutral wire directly through the

terminal block to the battery, with a master-switch intervening, while another wire from the battery passes through the terminal block to the contact of the selector-switch which is common to all speeds. The current travels from one terminal of the battery through the depressed push button on the selector-switch, down and around the coil selected, and then back to the other terminal of the battery.

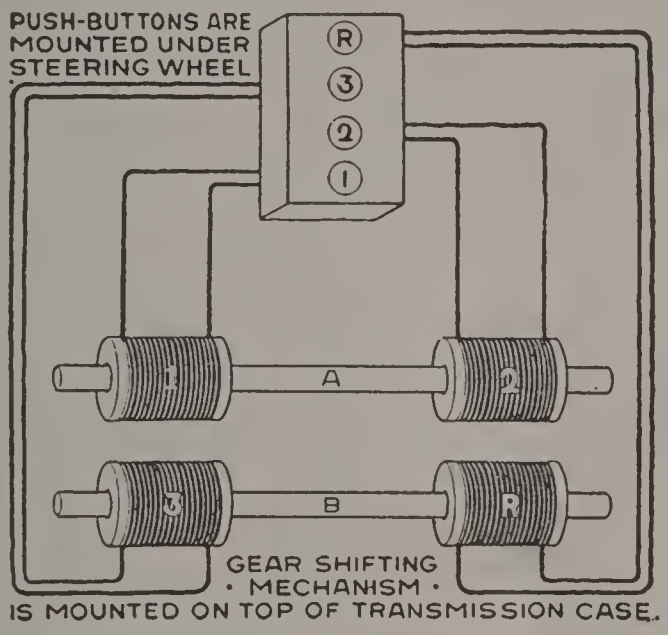


Fig. 238

Connections of the Magnetic Gear Shift

The Vulcan electric gear shift mechanism consists of a case which is attached to the transmission housing. This case, in turn, carries the magnets or solenoids. These in turn surround the plungers on which the shifting forks which move the sliding gears in the transmission are mounted. In this case, also, is carried the operating mechanism by means of which the gears

are mechanically drawn to their neutral position through a connection with the clutch pedal. The case is divided into two compartments, the smaller of which is a pocket in which the operating mechanism for the neutralizing of the gears and the operation of the master-switch is carried. This compartment is entirely enclosed on the bottom, and is not open to the transmission case.

The neutralizing mechanism consists of two shafts on which cams are mounted. One of these shafts carries a pawl which engages with a latch on a rocker arm. Upon the opposite end of this rocker arm shaft is mounted a lever through which the connection with the clutch pedal is made.

Assuming that all gears are in a neutral position (that is, the sliding gears are not in mesh), and it is desired to start, the first speed button on the selector-switch is depressed, closing one break in the electric circuit. The operating lever and the shaft on which it is mounted are rotated and the master-switch is pulled into engagement through its connection with the operating mechanism which engages the switch stem. As the gear flashes into mesh, and is within ⅛ inch from being "home," the master-switch snaps out instantly, due to the action of the master-switch spring, thus breaking the electric circuit. The actual time of engagement during which current is being drawn from the battery is less than 1/3 of a second.

Being in first speed, and desiring to proceed

to another, the other speed button upon the selector-switch may be depressed at the convenience of the driver. Then, when it is desired to shift, the clutch is fully depressed as before.

As the neutralizing cams rotate toward the center, they press against a boss on whichever side the gear is in engagement. This mechanically pulls the shifter fork and gear with which it is engaged back to neutral position, before the next shift can be made. The electric circuit is again made complete, the current flows from the battery through the solenoid selected and the proper gear immediately jumps into engagement. This action is the same for all speeds in the transmission.

Should it be desired to stop, the neutral button on the selector-switch is pressed. This action throws any other button which may have been depressed out of contact, that is, it automatically raises any other button which may have been depressed previously.

Any selection may be made, at any time, by pressing any push button on the wheel. This selection, however, does not necessarily influence the changing of the gears in the transmission. In fact, nothing happens until the master-switch is closed by the pressing, all the way down, of the clutch pedal.

In the operation of this device the clutch pedal may be slipped or fully released without any action taking place in the gear shift mechanism itself. This is due to the fact that the

operating lever is attached to the clutch pedal by means of an operating rod provided with a link mechanism, which allows the clutch pedal to fully release the clutch before it starts to pull on the operating lever.

Magnetic Transmission, see *Change Speed Gears.*

Magneto; see *Ignition, Magneto.*

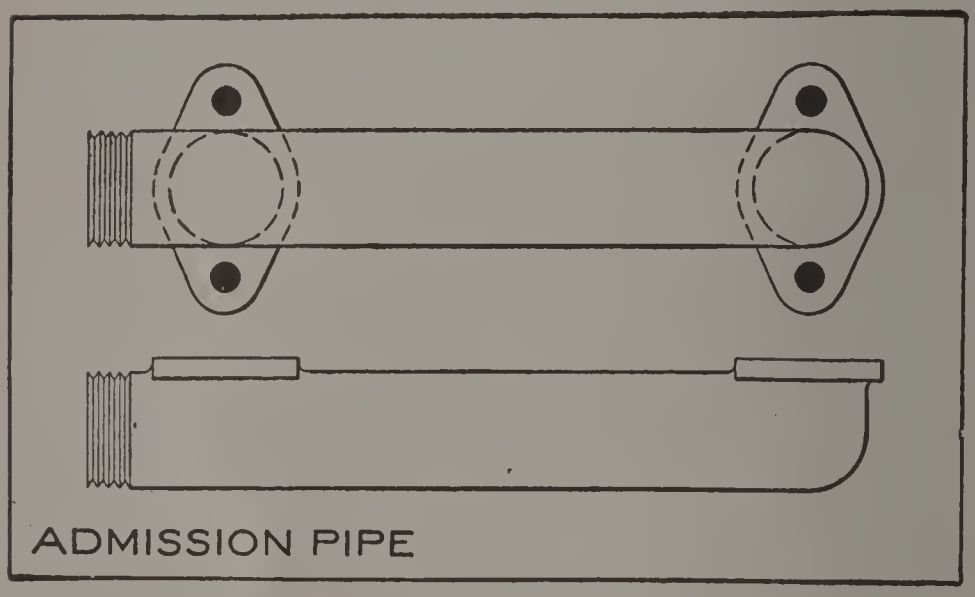


Fig. 239

Manifold, Inlet. The internal diameter of the admission or inlet-pipe leading from the carbureter to the admission-valve chamber should not exceed one-fourth the diameter of the motor cylinder.

This limitation is necessary in order to produce as great a partial vacuum as is possible in the admission-pipe. The carbureter should be placed as close as possible to the admission-valve chamber of the motor in order to secure

the best results. Short turns or bends in the admission-pipe greatly increase the air-friction in the pipe, and at high speeds greatly diminish the volume of the charge drawn into the cylinder by the inductive or suction action of the motor-piston. An admission-pipe with a side inlet and short bends, for a two-cylinder motor, is shown in Fig. 239. Such forms of construc-

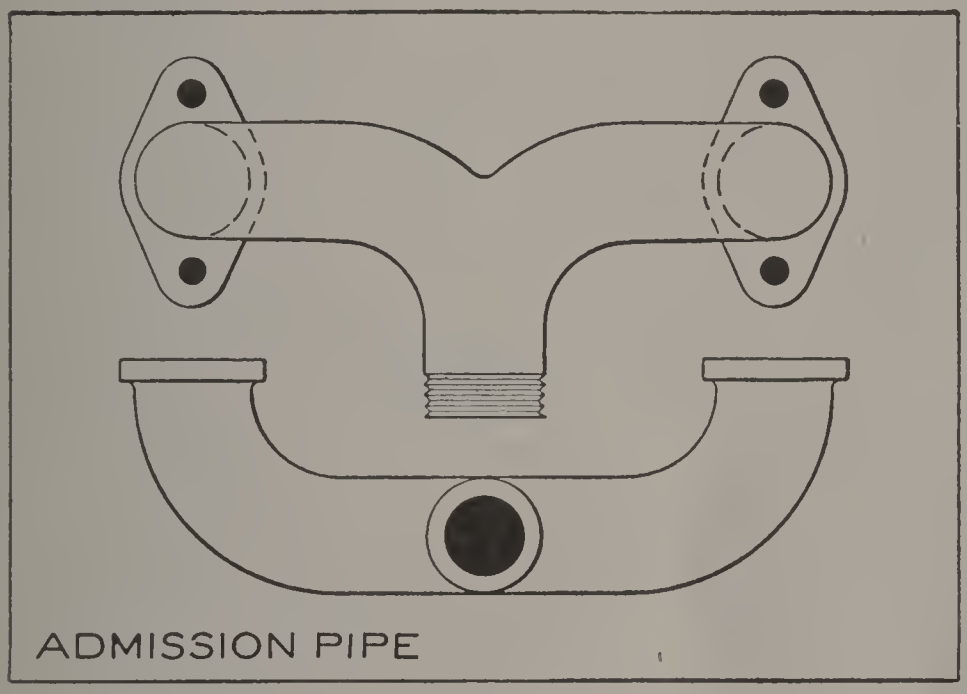


Fig. 240

tion should be avoided whenever possible. Fig. 240 shows an admission-pipe of approved design, with long bends, for a two-cylinder motor. The radius of curvature of the pipe on its center line should not be less than twice the outside diameter of the pipe. If space allows, a radius of three times the outside diameter of the pipe will give better results than two diameters.

The desire to prevent condensation of the gasoline vapor in the inlet manifold has led many designers to fasten the carburetor flange directly to the cylinder casting at the point of entrance to the inlet valve passages. Others have either completely or partially water-jacketed the inlet manifold for its entire length. In all cases, the distance between the carburetor mixing chamber and the inlet valve port is made as short as possible.

A troublesome condition on many cars is that caused by minute air leaks in the inlet piping and connections. If carburetor adjustment is difficult, squirt liquid gasoline on the inlet connections with the engine running. Any change in engine speed is a sure indication that one or more air leaks exist.

Motor, Electric Vehicle. A well designed motor for use in connection with a storage battery for automobile propulsion must be capable of withstanding an overload of over 100 per cent for at least thirty minutes at a time, or for even a longer period, without unduly overheating. The motors used on electric automobiles are usually series-wound, as this type of winding has been found to give the most satisfactory results in general use.

There are three types of electric motors in general use, these are:

Shunt-wound motors, in which the field-magnets are wound with a great many turns of

very small wire, the ends of which are directly connected to the terminals of the commutator brushes.

Series-wound motors, which have the field-magnets wound with a few turns of very large wire. One end of this wire is connected to one commutator brush terminal. The other end of the wire on the field-coils, and the other brush terminal being connected with a battery or other source of current.

Compound-wound motors are a combination of the above motors, having the field-magnets double-wound, that is with both shunt and series-windings.

The armature of an electric motor is built up of a number of disks of sheet iron, which are separated from each other by a suitable coating of varnish or by the use of thin sheets of paper between the disks, this is to prevent what are known as eddy currents, which are a source of constant trouble if not eliminated.

The function of the commutator of an electric motor is to receive the current from the battery or other source of power, by means of the brushes, and transmit it to the windings or coils upon the periphery of the armature.

The essential features of an electric motor are as follows:

The brushes, which are located upon and around the periphery of the commutator and serve to transmit the current to the commutator from the outside source of supply.

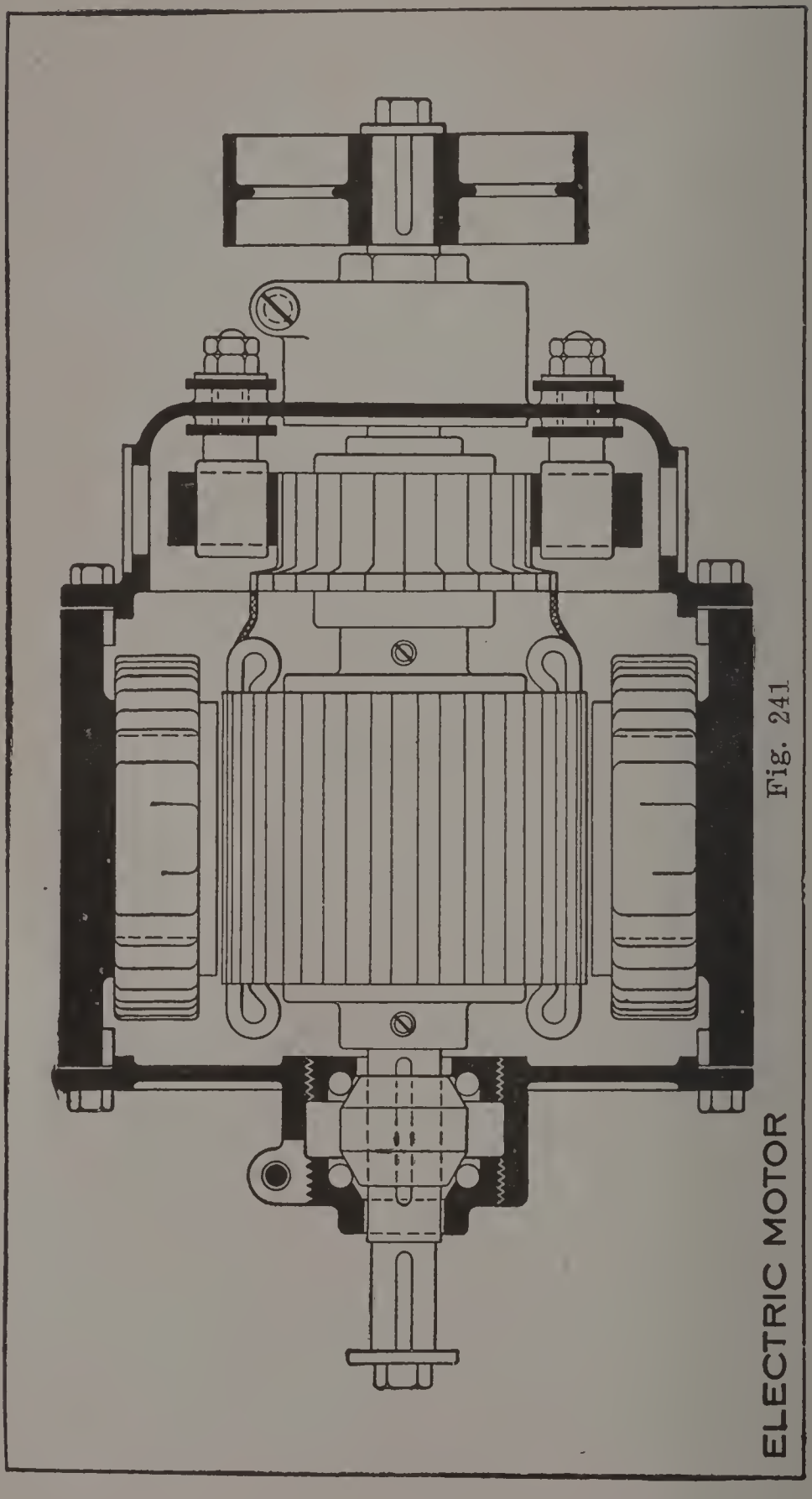


Fig. 241

The commutator or current distributor, and laminated wrought iron armature.

The field-magnets and pole-pieces; the latter are usually an extension of the magnet core.

The magnet frame, usually of cast steel.

Figure 241 shows a form of series-wound electric motor of the style most commonly used for automobile work. The motor is of the four-pole type, having its field-coils arranged at equi-distant points around the periphery or circumference of the armature. The armature shaft is carried by ball bearings, with suitable screw and clamp adjustment as shown. The armature is of the slot-wound type and has a commutator with self-adjusting carbon brushes. The left-hand extension of the armature shaft is fitted with a key and washer for the driving gear or sprocket, while the right-hand end has a pulley or brake wheel to use for stopping the car under ordinary conditions of travel. The magnet frame is of cast steel, and the magnet cores and armature disks of laminated wrought iron. The field-coils are machine-wound, and the armature coils form-wound, while both are thoroughly taped and waterproofed. The commutator generally has the same number of sections as the armature has slots and is usually of large diameter and wide contact face.

Electric Motor Troubles. Electric motor troubles may be classed as follows: Open-circuits, improper connections and short-circuits.

An Open-circuit may be found at any one of the following places:

Battery terminals. These may be badly corroded or worked loose, so as to form a poor or improper electrical contact.

Controller. A connection may have worked loose, or the spring contact-fingers are not making good contacts.

The removable plug may be out or not making a proper contact.

Brushes. One of the carbon brushes of the motor may have fallen out, or the brush springs may be too weak to insure a good contact.

The reversing switch may be halfway over, thus leaving the batteries and motor on an open circuit.

All points of contact, such as terminals or binding-posts, brush-holders, switches and controller spring contact-fingers, should be bright and clean so as to give a perfect metal-to-metal contact.

The fact that the car will not start and the ammeter shows no current indication is generally an indication of improper battery connections.

When the different trays of the battery are not properly connected together, short-circuits will occur between these sections and run down or exhaust the batteries in a very short time. All battery terminals should be plainly marked so that it is impossible to make wrong connections. If the trouble above stated occurs the

battery trays must be wrongly connected amongst themselves.

If the ammeter indicates a large current and the motor refuses to turn, the trouble is what is known as a short-circuit, or a path for the current outside of the motor.

Lift one of the commutator brushes, and if the amperage shown by the ammeter drops, or perhaps disappears altogether, one of the field-coils is short-circuited or there is a broken wire touching some part of the metal of the car or an exposed portion of another wire.

Electric Motors, Speed-Regulation of. The speed and consequently the power of an electric motor may be varied in three ways, as follows:

First, by introducing variable resistances in the motor and battery circuit.

Second, by varying the voltage of the batteries by different combination of the battery trays.

Thirdly, by connecting the field-coils of the motor; all in series, in series-parallel and all in parallel. Various other combinations of the above named methods may also be had.

Muffler, Exhaust. When the exhaust gases of an explosive motor are allowed to pass out through the exhaust pipe directly into the atmosphere, the sharp explosions rapidly succeeding each other are very annoying, and it is for this reason that the device termed an exhaust muffler is, or at least should be, used.

Various types of mufflers are in use, each no doubt possessing its own particular merit. The function of the muffler is to deaden the noise of the escaping gases, and the general requirements of the device are as follows: (1) It must be built strong enough to withstand the force of any explosion liable to occur within it, due to the escape of an unexploded charge, which may take place in one of the engine cylinders. (2) It must check the velocity of the escaping

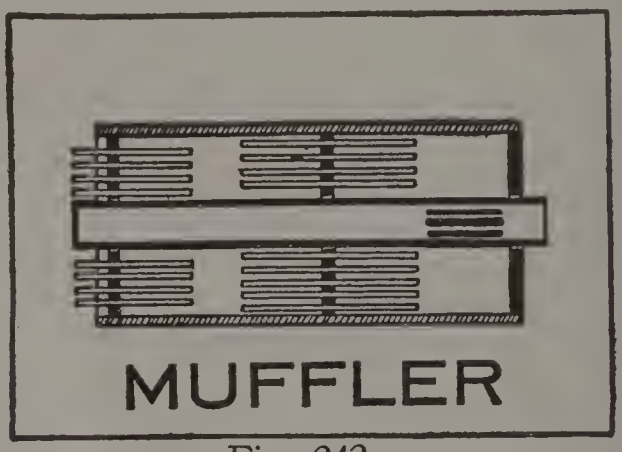


Fig. 242

gases without causing too much back pressure on the motor. (3) It must deaden the noise. The last two requirements may be attained by: (a) Breaking up the gases into a number of fine streams; (b) Allowing the gases to expand and cool; (c) Reducing the pressure of the gases, until they are as nearly as possible at atmospheric pressure.

The terminal or exhaust pressure ranges at from 30 to 50 pounds per sq. in. above atmospheric pressure, while the temperature will be 800 to 1100 degrees F.

Muffler Cut-Outs. Mufflers are generally equipped with muffler cut-outs, which by-pass the gas so that it exhausts direct into the atmosphere with its attendant noise. There are three reasons why they are so equipped, namely: to tell if the engine is exploding regularly; to clean the exhaust pipe; to have it act as a safety valve in case of explosions in the muffler. If the power of the engine increases when the muffler is cut out, it is a sure sign that the muffler is of defective design or needs cleaning.

Muffler Cut-Out Valve. One form of cut-out valve is shown in Fig. 243. It is inserted in exhaust pipe P, by sawing a hole in its under

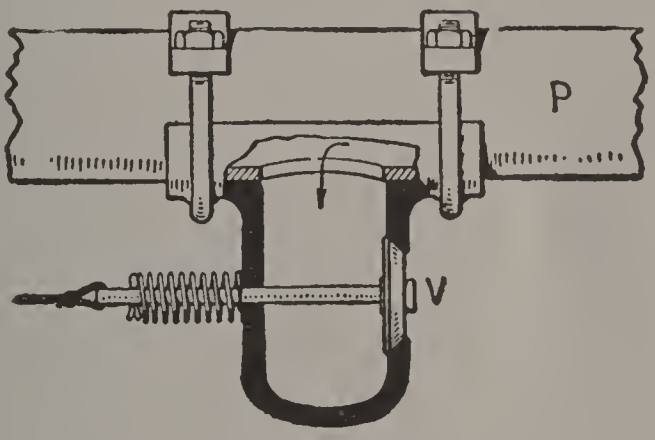


Fig. 243
Muffler Cut-Out Valve

side. The cut-out valve housing clamps to the pipe by a couple of V-clamps. The valve is carried in a cylindrical compartment under the exhaust pipe, and consists of a spring closed poppet valve a little larger in diameter than the internal diameter of the exhaust pipe. It opens against the exhaust pressure to prevent leakage.

Care of Mufflers. From time to time, all mufflers should be cleaned, because it will be found that they will contain a considerable amount of carbon deposists. These deposits not only tend to increase the back pressure, but they retain the heat of the exhaust, thus allowing the gases to escape at a higher temperature than they should. A muffler should be taken apart and cleaned once a year, or oftener if there are any indications of loss of power, resultant from back pressure.

A frequent cause of damaged or broken mufflers is the practice of ignition testing employed by some mechanics. In case of trouble with either source of ignition, the car is run at a rather high speed on the good system, and the ignition switch is then quickly turned to the faulty side. If no explosions result, the switch is again changed. In the time during which no explosions occurred in the engine, the unburned mixture was pumped back into the muffler. When the switch is thrown to the good side, the first power stroke sends a flame into the muffler with the result that an explosion occurs there, usually damaging the muffler seriously.

Packing. Packing or material for making gas, or water-tight joints is of various kinds. Asbestos packing comes in sheets, called asbestos paper or board, in the form of woven cloth, and also as string or rope. Rubber packing is made in sheets, either plain or with alternate layers of canvas and rubber. Some forms of

packing are known as Rubberbestos, and Vulcabestos, and are made of asbestos, impregnated with rubber and afterwards vulcanized.

Picric Acid. Gasoline will absorb or take up about 5 per cent of its weight of picric acid. The addition of a small quantity of kerosene will enable the gasoline to absorb about 10 per cent of pircric acid.

Picric acid is only dangerous when fused, or when in a highly compressed state.

An increase in motor efficiency of about 20 per cent is claimed for the picric-gasoline mixture.

About three-tenths of a pound of picric acid is required for each gallon of gasoline. The mixture should be allowed to stand for two days, agitating occasionally during this time, then strain through two or three thicknesses of very fine muslin before using.

It must be remembered that picric acid is an etching ingredient, which is another way for saying that it will destroy the cylinder walls.

The explosive force of picric acid is very much overrated. If thrown upon a red hot plate of iron, it simply burns with a smoky flame, and striking a small quantity of it upon an iron anvil will not explode it.

Piston Head Scraper. In most engines the piston heads can be scraped clean of carbon without removing the pistons from the cylinders, by means of specially formed scrapers introduced through the opening over the valves, or

through the spark plug holes when the latter are horizontal. The form and size of scraper will depend on the particular engine, but almost any suitable form may be made from 5-16-inch steel tubing about 12 inches long having the ends hammered flat, and turned over at right angles in a vise. The ends are then filed straight, and sharp, and the shank of the scraper may be bent to right or left, if necessary, or left straight. Frequently two scrapers will be needed in order to use both right and left hand bends. The advantage of tubing for this purpose is that no blacksmith work is necessary.

Platinum. The contact points of the vibrator of an induction coil should always be of platinum. German silver or any other metal spoils the quickness of the break on account of the greater tendency of the contact-points to carbonize, when of any other metal than platinum. Spark plug points should also be of platinum or iridio-platinum, which is better yet, as it is more capable of withstanding the intense heat in the combustion chamber than the platinum itself. Any other metal than platinum (except gold) will turn green or black if tested with nitric acid.

Polarity. To ascertain the polarity of the terminals of a storage battery or light circuit, place the ends of the wires on the opposite ends of a small piece of moistened litmus paper. The

wire on the side of the paper which has turned red is the negative pole of the battery.

Porcelain. Porcelain tubes used for the insulation of the center rod of a spark plug have higher insulative properties than lava or mica, but on account of the liability of the porcelain to break from too sudden change of temperature, it is not as reliable as other forms of insulating material.

Pounding—Causes of. The most obvious cause of pounding is that of a spark advanced too far. This, however, nearly always occurs upon hills, in deep sand or mud, or elsewhere, whenever the engine is laboring very hard. In the case of too far advanced spark, manipulation of the spark would only make the pound worse than ever. So, too, if the spark was normally set too far advanced, it would pound more at high speeds than at slow, just the reverse of the actual case.

Preignition causes pounding, and is itself caused by overheated piston or cylinder walls. Glowing points or deposits of carbon within the cylinder, as well as faulty or uncertain ignition also cause it. Leaks in the chamber are sometimes the cause of pounding, so too, are looseness of parts. Among the latter may be cited: connecting rod bearings, main bearings, loose flywheel, cracked flywheel, other lost motion. Beyond these things, the only other cause of pounding is that of some moving part which strikes as it rotates.

Preignition—Causes of. If the inside surfaces of the combustion chamber are free from sharp corners or projections formed in casting, preignition is probably due to the combined influences of high compression, and carbon or dirt on the piston head. Next to the exhaust valve itself the piston head is the hottest part of the engine, since it cannot be water cooled. For this reason it is much more important to keep the piston head clean than the other surfaces exposed to flame, and this is best accomplished, first, by the use of a good non-carbonizing oil, and, second, by thoroughly screening the air intake. If preignition is troublesome it will pay to fit a dust screen underneath the engine in case none is already provided, since whatever dust touches the piston head will be held there by the oil, and will be fully as effective in causing preignition as the same amount of carbon. The intake itself should draw air through at least one, and preferably two or more fine wire gauze screens of sufficiently large area to permit the air to pass through them slowly. These screens should be removable, and should be inspected, and cleaned with gasoline and a toothbrush as often as may be necessary. It will be found that the fitting of a suitable dust screen beneath will make an immense difference in the amount of cleaning, which the gauze screens require. In the manufacture of high classed motor cars the greatest care is taken in scraping the walls and dome of the cyl-

inder castings forming the combustion space, the aim being to remove every projection that might cause a pre-ignition point as also to remove every burr, or rough spot to which foreign matter would adhere. The lubrication system of a car is a most important factor in the elimination of preignition due to the proper amount of oil being fed to the cylinders at all times.

Pump, Water. The circulating pump is used in the belief that it affords a means for regulating the temperature of the jacket water supply, which would not always be the case with a thermal-syphon system. Such is not the case, as the pump, being driven direct from the motor, operates at a speed which varies with the motor speed. On starting the motor, it pumps cold water into the jacket. It pumps slowly at slow speeds, although the motor may be taking a full charge and heating rapidly. It pumps fast at high speeds, although the wind pressure and its consequent cooling effect may be very great. If a circulating pump could be used in connection with a device to control the regulation of the motor temperature, the results would be more satisfactory.

Rotary pumps used in the water circulating system of gasoline automobile motors are of two forms, centrifugal and positive, or force-feed. A positive or force-feed rotary pump is shown in Figure 244. An annular ring around the pump shaft carries two blades, one of which is

hinged to, and the other attached directly to

Fig. 244

the pump shaft. The outer ends of the blades are supported in the periphery of the annular ring, and rotate eccentrically with it. The pump shaft is concentric with the pump chamber, but the annular ring is located eccentrically around the shaft, which drives it by means of the fixed blade on the shaft.

Fig. 245 illustrates another form of positive-feed rotary pump, in which the pump shaft is eccentrically located in the pump chamber. A short cylinder which forms a part or portion of the pump shaft, carries two blades in a slotted opening parallel to, and coincident with the axis of the pump shaft. These blades are kept in contact with the interior periphery of the pump chamber by means of coil springs, located between the blades as shown. Rotation of the cylinder in the pump chamber causes a sliding

or reciprocating action of the blades, due to

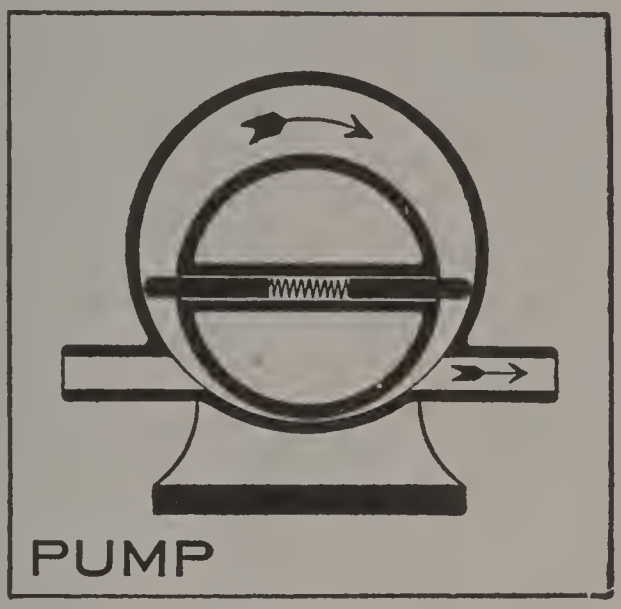


Fig. 245

the pressure of the coil springs between their inner ends.

Pumps—Centrifugal. In this type of pump the height of lift is governed by the tangential force. Owing to this fact centrifugal pumps for use on automobiles may be made of aluminum for the housing, as it is both light and strong, fully able to withstand the pressure, there being no rubbing surfaces. The wheel, however, should be made of phosphor bronze of a good grade. In these pumps the suction inlet is usually at one side surrounding the axis, see Fig. 246. The pump should be geared to a speed as high if not higher than the crankshaft speed. The minimum peripheral velocity of the pump wheel should be 500 feet per minute. For automobile service the general rule is to have a

three vane wheel, and the curving is away from the direction of rotation.

Pumps, Water Circulating. If steam is seen coming from the relief, or outlet of the water

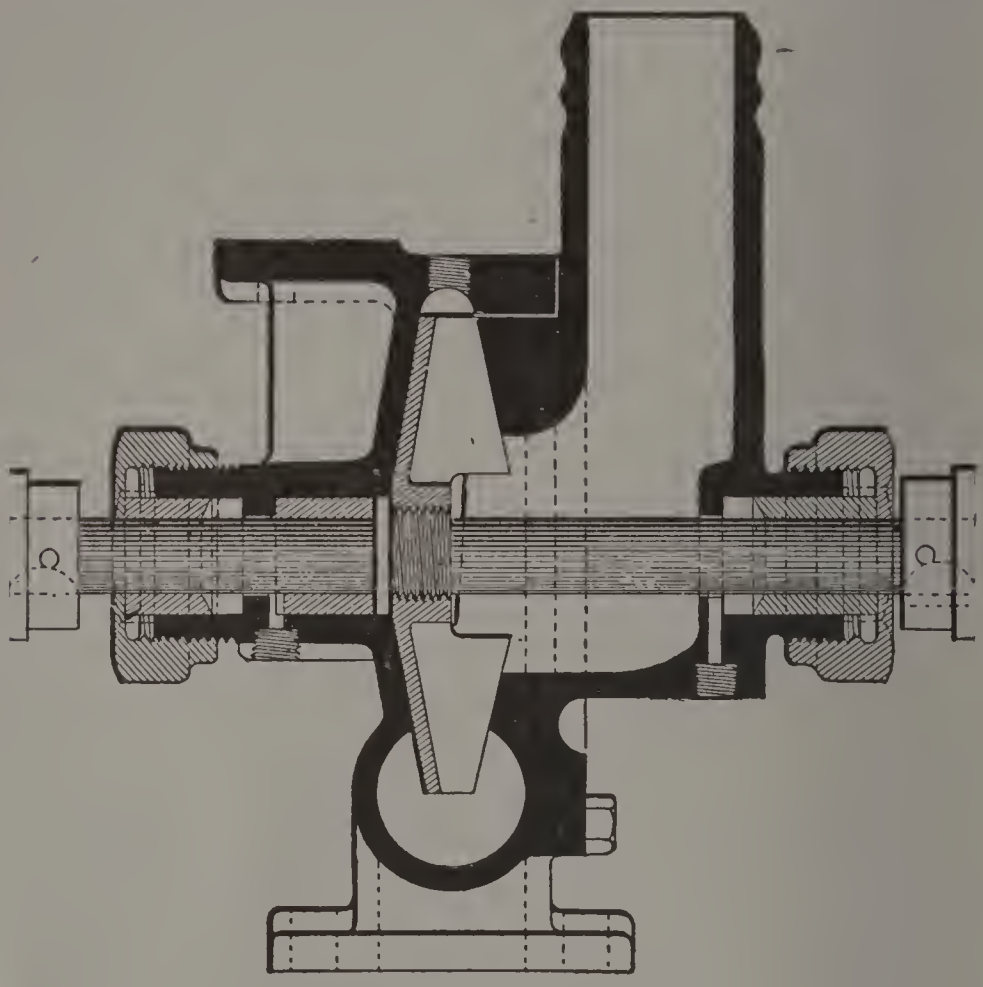


Fig. 246
Section of a Centrifugal Water Pump, Showing Entrance of Water at the Side, Around the Shaft

circulating system, look for a blockage of the circulation, or failure of the pump.

If some of the radiator tubes are cool and others are hot, look to the pump.

To test the pump before starting, run the motor for a few minutes. Then ascertain how

long it takes before the top radiator tubes are thoroughly hot. If the heat of the pipes is uniform the circulation is all right.

Rheostat. A rheostat is a device for regulating the flow of current in a closed electrical circuit, by introducing a series of graduated resistances into the circuit.

Rubber, India. All articles made of commercial rubber should be kept from contact with oil, kerosene, gasoline or grease if they are to be kept in good condition. Vulcanized rubber should not be exposed to a temperature of more than 130 degrees, Fahrenheit. Commercial or vulcanized rubber contains not to exceed 30 to 35 per cent of pure India rubber, as its stretching quality, stickiness and rapid deterioration under the action of light and air make its sole use undesirable.

Rubber Cement, How to Make. Marine glue, so-called, is an excellent cement. This consists of one pound of caoutchouc to one gallon of coal tar naphtha, and twenty pounds of shellac. Heat gently and pour on metal plates to solidify. When needed, melt. By using more naphtha, this is made thinner so as to stay liquid. The sulphur in this is in the caoutchouc, but if found insufficient in any one case, more sulphur may be added to the cement in the powdered form, when making it up, or if necessary, when remelting.

Another excellent cement is gutta-percha

cement. The composition of this is two parts of gutta-percha to one part of common pitch. It is melted together, and well-stirred in the melting, the stirring being fully as important as the materials. When thoroughly melted and stirred, it is poured into cold water. This makes it into a hard brittle substance, which softens at a low temperature, and at 100 degrees is a thin fluid. Like the former recipe, this carries its own sulphur in the gutta-percha, but if more is necessary, it can be added as a powder. In this case, it is not advisable to add the sulphur during the remelting process, but it should be put in while making up a batch of the cement.

As a rule, as little cement should be used as is possible to make a good job. Moreover, all cement should be given plenty of time to dry. Rubber surfaces to be united should be thoroughly cleaned, either with naphtha or with a thin cement. When the latter is used, it is brushed over the surface very lightly, using a fine brush, and then the surfaces are heated gently. This helps the whole operation, because it both softens the rubber, and evaporates the solvent, which is then unnecessary to complete the operation, having served its usefulness.

In addition to the various substances mentioned before for cements, it is very often necessary to have the cement dry very rapidly. In these cases, specific driers are added, and may usually be added to any cement at will, the quantity added being measured only by the re-

quired speed in drying. Then there are cases where certain degrees of tenacity are required. For these, other gums are added, as rosin, mastic, gumlac, etc. These, however, should be used only when needed, and much discretion should be used in adding them to an already very satisfactory cement.

Running Gear. A complete running gear includes the frame, springs, wheels, motor, speed-change-gear, axles and the machinery of the car except the body. The French word, chassis, is sometimes used to designate a running gear,

Secondary Current. The current which takes its rise in the fine wire of the induction coil, and which flows through the wire to the spark plug, is induced in the fine wire by the sudden reversal of the magnetism of the iron core.

This change of magnetism is caused by the sudden interruption of the primary current.

Self-firing, Causes of. If the motor should continue to run after the switch has been opened, it is due to an insufficient supply of lubricating oil, causing the motor to overheat, or to the presence of soot or some projection in the combustion chamber becoming incandescent. It may also be due to lack of water or to the water circulation working poorly, causing the motor to overheat.

Shaft Drive. The principal advantages which may be advanced for the shaft drive are, absence of noise, convenience with which all the parts may be housed in oil and protection from

dust. It is especially adapted for use upon cars carrying their engines in front, with the crank-shafts parallel with the length of the car, as the direction of the power shaft does not have to be changed until the rear axle is reached, and as the power must also pass through one set of bevel gears, it is more efficient.

The principal disadvantages of the shaft drive are that it is difficult to repair; it is some-

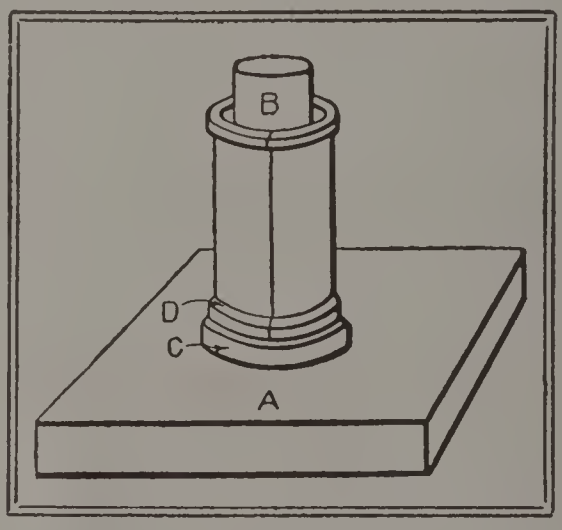


Fig. 247
Pouring Parson's Metal

what more complicated; it has considerable end-thrust and it is claimed that it is harder on the tires.

Shop Kinks. To reline a journal box with Parson's white brass, proceed as follows: Prepare a reasonably smooth cast iron plate A, Fig. 247, which is bored to receive a vertical mandrel B about 3/16 inch smaller in diameter than the finishing bore of the box. An annular brass ring C, about ½ inch wide, and whose in-

side diameter is about ⅛ inch smaller than the outside diameter of the end flange D of the box to be lined, is then located on the iron plate concentrically with the mandrel, and secured by means of pins or otherwise. This ring serves as a support for the box itself, and in the process of pouring, the space between the ring and mandrel is filled with white brass which is afterward turned off. Any imperfect metal which may be poured will

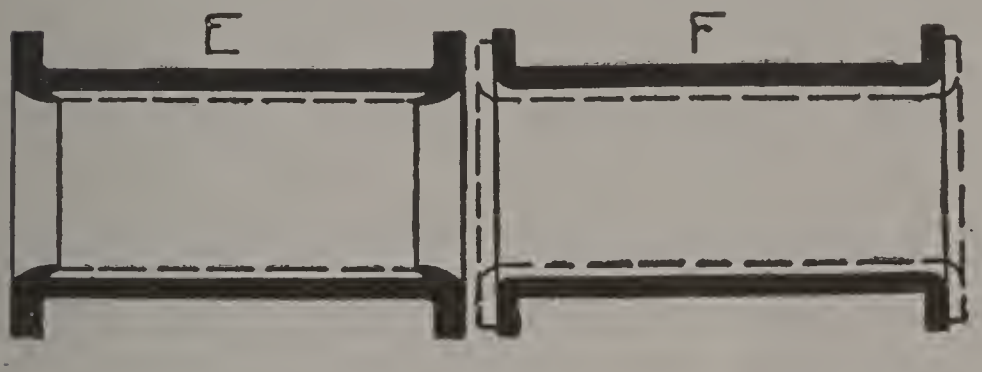


Fig. 248

find its way either into this space or into the space above the box, leaving the lining of the box itself perfectly sound. The box itself is assumed to have been suitably counterbored and recessed to hold the lining as shown in the sketches E and F, Fig. 248. It is preferable to use the arrangement shown at F and allow the lining to extend beyond the ends of the box, and form the outer surface of the flanges. In this case the diameter of the flange formed by the lining will be the inside diameter of the sup-

porting ring, which will be slightly smaller than the diameter of the flange of the box itself.

The halves of the box—if it is split—are wired together and the box and the mandrel are heated by torches and assembled as shown in the sketch. A second ring—not shown—similar to the supporting ring is placed on the top of the box, and all the cracks are luted with moist fire clay. Meanwhile, the white brass has been melted in a kettle to a fairly high heat somewhat higher than the pouring temperature. While it is being melted, it is kept covered by about 1 inch of powdered charcoal, which excludes the air. When the maximum temperature is reached, the charcoal is quickly skimmed off and a handful or two of powdered salammoniac is thrown on. The salammoniac is immediately volatilized and forms a heavy, though colorless gas which shuts off the air from the surface of the metal and causes it to stay bright. The pouring is then done with all possible haste, and on cooling the metal will be found perfectly homogeneous and solid. If the box is split the lining can be condensed by pening. If the box is solid, the lining is simply bored to the proper size.

To Restore a Sagged Frame. A frame which is sagged to the extent of permanent deformation can be restored so as to approximate its original shape, by heating it in a charcoal fire with an air blast. To do this properly, it will most likely be necessary to cut out the rivets,

so that the side members can be handled independently. A good plan of procedure is to inclose the bent portion of the frame in a section of stovepipe of sufficient size in which the charcoal fire is built. A length of 1-inch gas pipe, closed at one end, and having 5/16-inch holes, drilled at intervals of about 6 inches, is laid in the bottom of the pipe and furnishes the air supply from a bellows. When the charcoal fire is well kindled, the frame is introduced upside down, and is supported at the ends. The fire is then concentrated on the bent portion, and as the frame becomes hot it will straighten itself. It must be watched carefully and the air blast stopped as soon as the frame is seen to be straight. Most of the frames used in American cars are ordinary carbon steel, and require no special treatment. It will be well, however, on stopping the air blast to shift the stove pipe to a cooler portion of the frame, to permit the part which has been straightened to cool as quickly as exposure to the air will permit. A frame which has been sagged and straightened in this manner will require to be trussed to prevent recurrence of the trouble. As conditions vary so much the best rule to follow is to observe the truss arrangement on some similar car. The struts should be about 4 or 5 inches long, and should be located at the spots where the sagging has occurred. The truss rod itself should be about ½ inch in diameter, and drawn taut by a turnbuckle, which may be finally

tightened when the chassis has been assembled.

Spanish Windlass. The old fashioned Spanish windlass, in Fig. 249, may be occasionally employed where no other hoist is available. It is extremely handy in setting, and lining up motors, transmissions and rear axles. It consists of a round bar or piece of pipe, a piece of rope, and a lever such as a small crowbar or

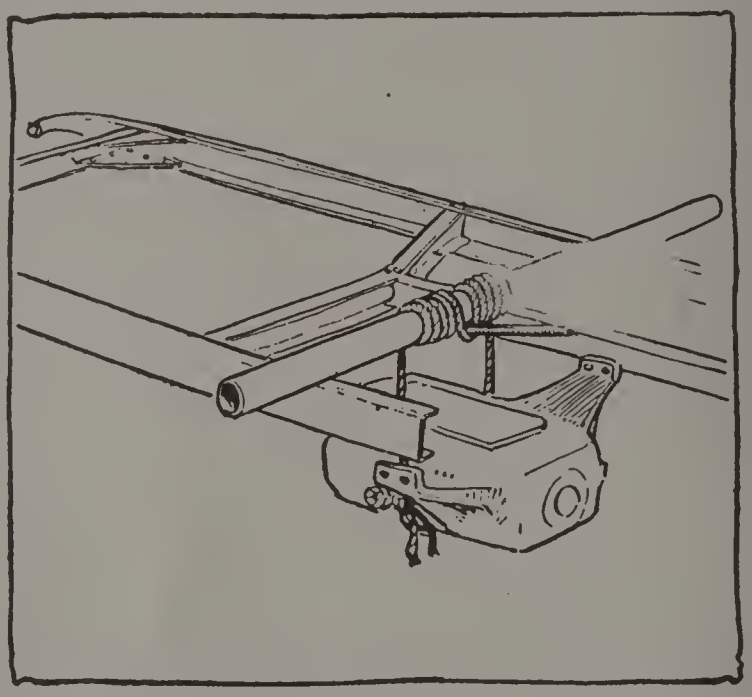


Fig. 249
Spanish Windlass

jack-handle; all of which are quite common to the ordinary repair shop. The round bar is laid across the side members of the frame, the rope is made fast to the object to be hoisted, a loop of it is wound around the bar as shown, and the lever inserted in the end of the loop. Although this is as old as the hills, it is not uncommon to see a man lying on his back, in a

most uncomfortable position, holding a heavy transmission case up into place while another is trying to locate the bolt holes, and adjust the liners; whereas, if this makeshift windlass were employed, one man could raise and set the gear-box with much less trouble.

Straightening Spindles. In Fig. 250 a tool is shown which is used in a local repair shop, for straightening spindles. The tool, which is of heavy construction, is placed in a vise; the

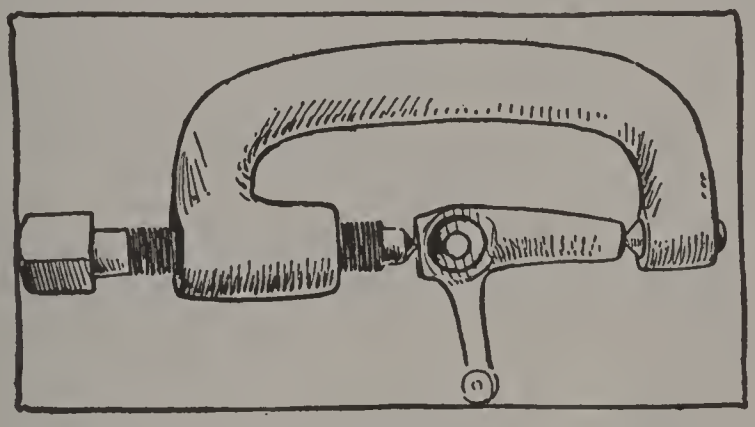


Fig. 250
Tool for Straightening Spindles

spindle is heated to a red heat, the ends cooled off with water, and placed between the centers, as illustrated. A lever is then placed between the bent portion of the spindle and the shank of the tool, so that when pressure is brought to bear on it, the spindle arm may be brought back into its normal position.

Cleaning Aluminum. Aluminum, such as used for foot-boards of cars, may be cleaned by using hyposulphate of soda, as this substance is a solvent of aluminum tarnish. The dirty sur-

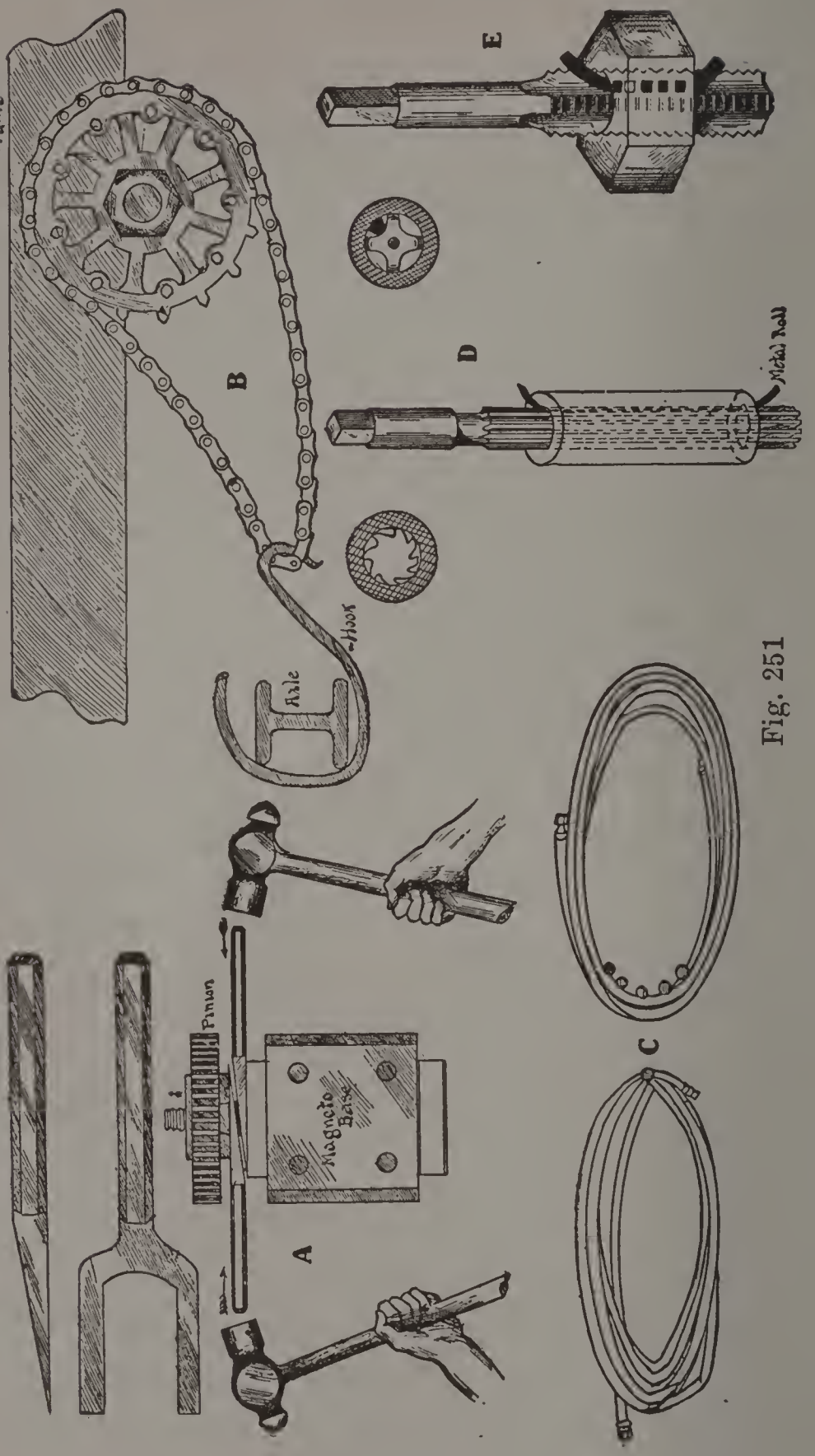


Fig. 251

face should be washed with a strong solution of the hyposulphate; then rinse the surface with water and dry.

Care of Tire Pump Leather. The proper lubricant for the cupped leather washer of the tire pump piston is vaseline. Oil is too thin and it tends to work into the rubber hose, and even into the tire itself if too much is used. Vaseline, on the other hand, clings to the leather and lasts a considerable time. If the leather becomes dry it does not hold air well, and pumping to high pressure becomes impossible, while the labor of pumping even to low pressure is greatly increased.

Replacing Broken Ball. When replacing a broken ball in a ball bearing it is better to renew the whole set, unless the new ball can be carefully gauged to be of the same size as the others. If this is not attended to, the new ball, having to bear more than its share of the weight, quickly succumbs. The greatest care should be taken, of course, to use grease free from grit, and to clean the balls and bearings before they are replaced.

Cleaning Tops. Tops may be cleaned by using gasoline, a little ivory soap and a brush. Sometimes, however, when cleaning with gasoline the water-proofing quality of the materials may be destroyed. This can be restored by an application of paraffine. Dissolve the paraffine with gasoline and apply with a clean brush, the gasoline will carry the paraffine into the fabric

and will evaporate, leaving the paraffine in the fabric.

Useful Hints. At A, Fig. 251, is shown a simple tool found to be universally useful for wedging off magneto driving pinions, and other small members fitted to coned shaft ends, with or without key retention. This can be easily made from a large file, or any piece of steel of sufficient dimensions, depending upon the work to which it would be applied. The opening in the fork need not be more than three-quarters inch for the average magneto, the tines about two inches long, and three-eighths inch wide and taper from nothing to about one-quarter inch at the thickest part. Two of these are needed and are placed back of the gear, the tapered portion of one piece resting on that of the other, as shown. To remove the gear the ends are driven in toward the centre at the same time. This exerts a lifting effort, due to the wedge action of the tools immediately back of the pinion. The advantage of this method is that the shaft on which the gear is mounted is not subjected to any side strains, such as would result if attempts were made to drive off the gear by holding an S wrench back of the gear and driving against it with a hammer. When removing worn sprockets from the counter shaft in order to replace them with new ones, trouble may be experienced in loosening the nut especially if the rear wheels have been removed. In such cases the chain may be utilized

to hold the sprocket in the manner shown at B, Fig. 251, by anchoring it to the axle with an S hook made of three-eighths inch cold rolled steel rod The sprocket will be firmly held and the nut removed without difficulty.

Although some grades of rubber hose are better than others, unless properly cared for even the best will deteriorate rapidly. Among the factors which make for rapid wear are careless stowage and abuse. The hose is left on the wash stand, cars are run over it, and when it has served its purpose, it is thrown in a heap and oil and grease accumulations soon work havoc with the rubber walls. A good rule to follow is to have a place for everything and everything in its place. It is not unusual to see a coil of hose carefully hung upon a nail, as shown at C, each coil having a sharp "kink" in it, both top and bottom, as indicated. This sharp bend tends to break the fabric walls, and the hose soon leaks. The proper way of hanging a hose is to use five or six wooden pegs arranged around an arc of a circle, as shown. Under these conditions the coils take a gradual curve, and do not assume a sharp angle as when but a single point of support is utilized. If the hose is one of some length a reel should be used.

Often when fitting bushings and parts, and in general operations where reamers are used it is found that the tool will be just a trifle undersize, or that it is desirable to have the

reamed hole just a little oversize. In such cases a simple expedient, as shown at D, Fig 251, will be found valuable. A small sheet of brass, or zinc is rolled in such a manner that it will fit between two of the cutting edges of the reamer. If the reamer is inserted with the roll of metal in place it will be evident that the reamer will be forced a trifle from the centre of the bore and the cutting edges of the reamer opposite the inserted metal roll will remove the metal. Very fine cuts should be taken, and the metal roll placed between different cutting teeth each time that the tool is used. In tapping out nuts it is often desirable to have the thread a little deeper than the standard, or to have the nut a loose fit on the bolt, as is sometimes necsesary when trying to place a machine screw nut on a carriage bolt. In this case a similar roll of metal may be placed between the cutting edges of the tap, as shown at E, Fig. 251.

Solder. Silver solders are generally used for very fine work. They are very fusible, and non-corrosive. Hard spelter is used for steel and iron work, and soft spelter for brass work.

When copper is soldered to iron or zinc, resin should be used, or if chloride of zinc is used for a flux, the joint should be washed afterwards to remove the acid. Un-annealed wires should be soldered at as low a temperature as possible. Solder is always an alloy of other metals. It must not only be more fusible than the metal, or metals to be joined, but it must have some chem-

ical affinity for them. Different kinds of solder are therefore employed for different purposes. It is called either hard or soft, according to its fusing point.

Solders and spelters for use with different metals, and their proportional parts by weight are

Solder for:

Electrician's use—1—Tin, 1—Lead.

Gold—24—Gold, 2—Silver, 1—Copper.

Patinum—1—Copper, 3—Silver.

Plumber's—Hard—1—Lead, 2—Tin. Soft—3—Lead, 1—Tin.

Silver—Hard—1—Copper, 4—Silver. Soft—1—Brass, 2—Silver.

Tin—Hard—2—Tin, 1—Lead. Soft—1—Tin, 1—Lead.

Spelter for:

Fine brass work—8—Copper, 8—Zinc, 1—Silver.

Common brass—1—Copper, 1—Zinc.

Cast iron—4—Copper, 3—Zinc.

Steel—3—Copper, 1—Zinc.

Wrought iron—2—Copper, 1—Zinc.

Fluxes for Soldering. Some good fluxes for soldering purposes are:

Iron or steel	Borax or sal-ammoniac.
Tinned iron	Resin or chloride of zinc.
Copper to iron	Resin.
Iron to zinc	Chloride of zinc.*
Galvanized iron	Mutton tallow or resin.
Copper or brass	Sal-ammoniac or chloride of zinc.
Lead	Mutton tallow.
Block tin	Resin or sweet oil.

*Chloride of zinc is simply zinc dissolved in hydrochloric (muriatic) acid, until the acid is eat or killed.

Scratched Cylinder. The cylinder may be temporarily fixed by taking it to a first-class tinsmith and having the scratches filled with silver solder. The soldered places must be then carefully scraped flush with the bore of the cylinder. The best way is to have the cylinder rebored and the piston-rings re-turned.

If the scratches are not too deep the cylinder can be rebored, and a new set of piston-rings made to fit the new bore. The limit to such an increase in bore is about one-sixteenth of an inch.

If the damage to the cylinder walls has been comparatively slight, due to the conditions being recognized early, the engine should be disassembled and the surfaces thoroughly cleaned of any dirt or carbon. After reassembling, the full amount of lubricating oil should be put into the engine, and with the oil should be mixed an amount of graphite, in either the amphorous or flake form, proportioned to the kind being used and the body of the oil. Continued use of graphite will tend to fill the small scratches in the metal.

Garage—Cleaning Floors. A hot saturated solution of common washing soda will do very well. This can be made up in quantities and stored against future use. If this method is used, be sure to reheat it before using, the boiling point being about right. Since that will be too hot to apply with the hands, use any old broom or brush to "slosh" it around on the

floor. An equally good, if not better, solution to use for this purpose is trisulphate of sodium, marketed by several chemical companies, and sold at from four to five cents per pound at retail. This can be used cold and will not injure the most delicate hands; on the other hand, it will clean them very thoroughly, so that users of this solution use it for the hands as well as for the floors. This is strong, however, and may be used to remove paint.

Protection From Fire. The recommendations of the National Fire Protection Association pertaining to garages and their operation are as follows: No dynamo or gas engine should be permitted where gasoline is stored or handled; all exposed lights should be eliminated; cleaning of acetylene lamps and removal or renewing of carbide should be carried on outside of garage; the residue of acetylene lamps should never be cast on the floor; machines should have oil tanks emptied before being put in the repair shop; the use of extension electric wires is condemned, as they may cause fire; motor testing should be done outside, for sparks might ignite the fumes of gasoline; storage tanks should be filled from outside of garage; all volatile oils should be stored in good, heavy tanks under ground, as far away from the building as possible; pipes for filling storage tanks should not pass through the garage in any way; a filling station should be twenty to thirty feet from the entrance to the garage, and

tanks of cars filled from there if it is necessary to fill them when the cars are inside of the garage; furthermore, the station should be fireproof, and all cars should be brought to this point for filling; smoking and carrying of matches, or use thereof should be strictly prohibited; floors should be kept free of oil drippings, and pails of sand should be kept handy in proximity to gasoline.

A garage of ordinary size should be equipped with at least four or five chemical fire extinguishers, and these should be placed so that they may be quickly reached by any one in case of emergency. The stream from such an extinguisher will smother a fire before it has done much damage if the flame can be reached within a minute or so of the time when it started. The chemicals usually used will not harm the finish of the car if the surfaces exposed are immediately washed in the usual way. Slight marring is of course preferable to destruction.

Spark Plugs. The trouble with motors misfiring, is generally due to dirty spark plugs. This is caused by using too much cylinder oil, which, when subjected to the intense heat in the cylinder, turns to carbon. This carbon deposits on the insulated porcelain and the body of the plug, and instead of the current jumping from the point in the body to the point in the porcelain and making a spark, it follows the easiest path, which is the carbon, and does not make a spark at the plug points at all. When

this occurs the motor will misfire. The first thing to do when a motor misfires is to test the spark plug. Turn the motor until the battery circuit is closed. Unscrew the spark plug from the motor, then reconnect the wire to it just the same as it was before. Lay the metal part of the plug body on the flywheel or some other un-

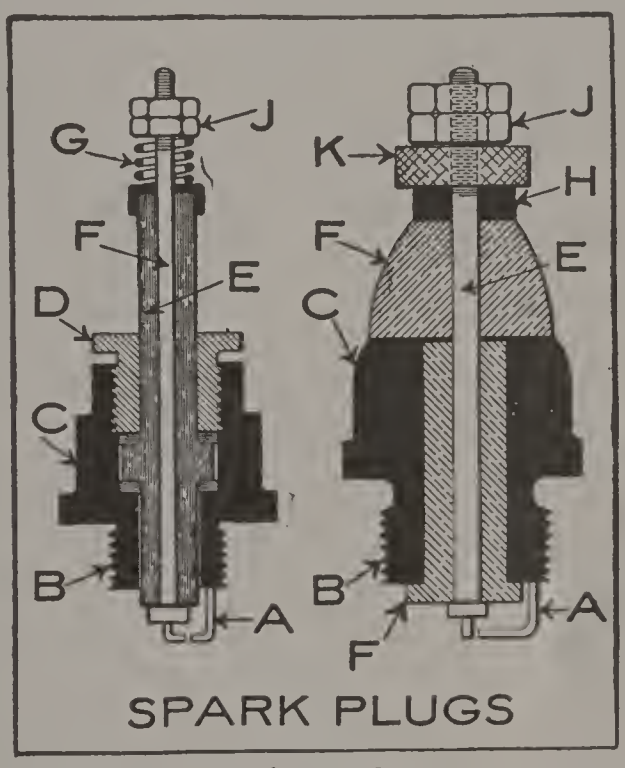


Fig. 252

A—Platinum point.
B—Thread.
C—Plug body.
D—Bushing.
E—Insulated terminal.
F—Porcelain bushing.
G—Expansion spring.
H—Asbestos washer.
J—Lock nuts.
K—Assembly nut.

painted part of the motor, being careful that the metal part of the plug body only touches the motor and that the porcelain part is clear. If the spark jumps in short jerks between the inner end of the porcelain and the interior of the plug body it is sooted, and needs cleaning.

If it jumps at the points as it should do, the trouble is elsewhere; probably at the battery, loose connecting wires, or the vibrator of the coil is not properly adjusted.

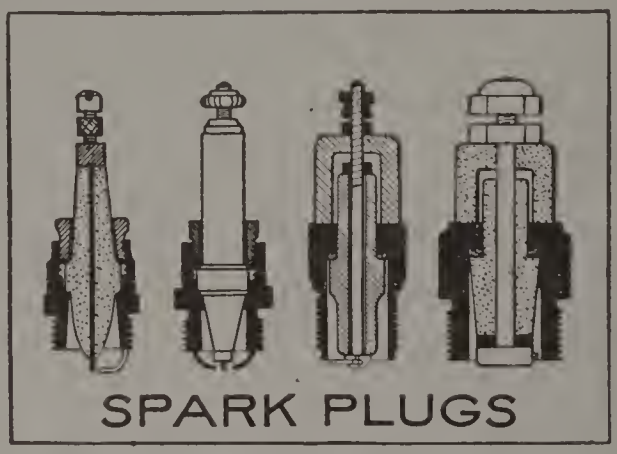


Fig. 253

To clean a spark plug properly use a 50 per cent solution of hydrochloric (muriatic) acid, washing the points of the plug with a tooth brush, occasionally dipping the plug into the

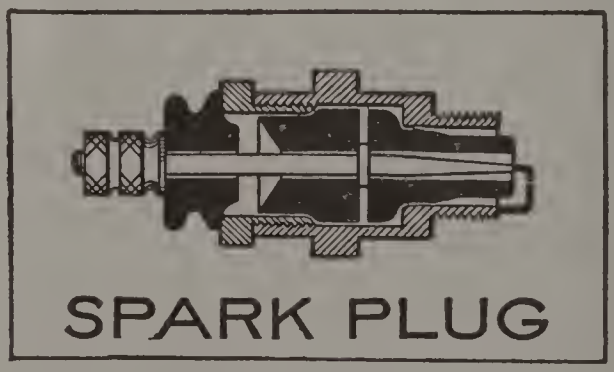


Fig. 254

acid. After cleaning the spark plug in this manner, rinse it in water.

Spark Plugs—Construction of. Two spark plugs are shown in Figure 252, which, while differing radically in their construction, effect the

same purpose, that of producing a spark or arc in the combustion chamber of the motor. The accompanying table and reference to Figure 252, will fully explain the construction of the spark plugs.

Cross-sections of four different forms of spark plugs are shown in Figure 253. All are constructed with a view to make the outside or extraneous path caused by sooting, as long as

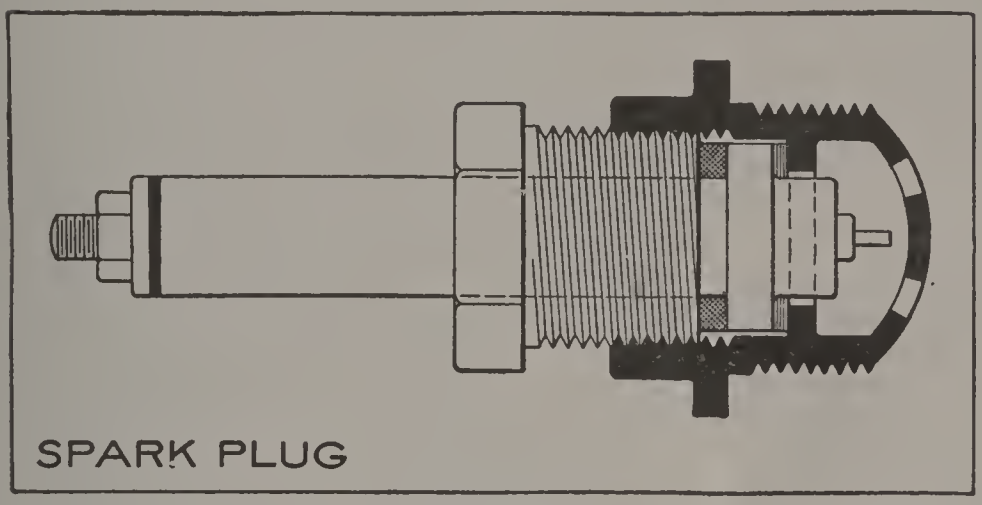


Fig. 255

possible, so as to prevent if possible short-circuiting of the plug from this cause.

Figure 254 shows a form of spark plug in which two extra air-spaces are provided, one between the center rod or terminal and the porcelain bushing and the other between the porcelain bushing and the shell or body of the plug.

The spark plug shown in Figure 255 has a closed chamber around, and over the center insulated rod or terminal; this chamber is a part

of the body of the plug and forms the other terminal of the plug. It acts as a small combustion chamber, and streams of fire are supposed to be thrown from the small openings in the chamber, when the arc or spark occurs therein.

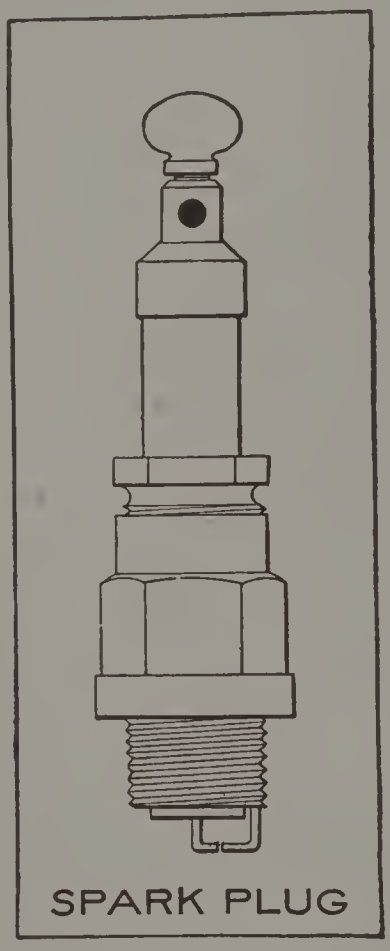


Fig. 256

An exterior view of a form of spark plug in general use is shown in Figure 256.

Spark plugs of American manufacture are made with three different sizes of threads: One-half inch pipe-size, the actual outside diameter of which is .84 of an inch, with 14 threads per

inch. Seven-eighths of an inch diameter, with 18 threads per inch, and .7 of an inch diameter, with 17 threads per inch. The last named one is the French, or Metric standard thread.

Specific Gravity. In the absence of a proper instrument, the specific gravity of gasoline or any other liquid may be obtained as follows:

Weigh a certain quantity of distilled water at 4 degrees Centigrade, or 39 1/3 degrees Fahrenheit.

Weigh the same quantity of gasoline or other liquid under test.

Divide the weight of the liquid by the weight of the water, and this will give the required specific gravity of the liquid.

The specific gravities of various liquids are as follows:

Alcohol at 15° C.	0.794
Acid, nitric	1.217
Acid, sulphuric	1.841
Ether at 15° C.	0.720
Naptha	0.848
Oil, linseed	0.94
Petroleum	0.878
Gasoline at 15° C.	0.680 to 0.720
Water, sea, at 4°	1.026
Water, pure, at 4°	1.0

The specific gravity of the electrolyte used in storage batteries is usually close to 1,250 under ordinary conditions. This figure will reach 1.300 or 1.310 with a fully charged starting and lighting battery, and may fall as low as 1.100 with a battery that needs charging badly.

The specific gravity of a storage battery should be tested while the battery is being

charged or immediately after the charge has been discontinued, never just after water has been added.

To test the gravity, it is necessary to use a hydrometer made and graduated for this work, the instrument being preferably enclosed in a tube fitted with a bulb and nozzle and called a hydrometer syringe. With the filling caps removed from each cell of the battery, the bulb is compressed, the nozzle inserted into the cell and enough liquid drawn up to float the hydrometer. The marking on the hydrometer stem at which the surface of the liquid remains is the specific gravity of that cell. The gravity should be nearly the same in all cells with a good battery. The liquid should be returned to the cell from which it was drawn.

Springs. The length and number of leaves in the springs of motor cars of similar weight and power vary, and without any reason for so doing. The general use of pneumatic tires hides many imperfections in this respect as well as in others. Springs of insufficient strength are a source of great danger, and frequent examination should be given to them. Springs are not necessarily of insufficient strength because they appear to be light. Short springs are not desirable, as they are more liable to break than a longer spring, the deflection per unit of length being greater. Stiffness in short springs is usually avoided by lightness, which is likely to lead to breakage, especially when the hole

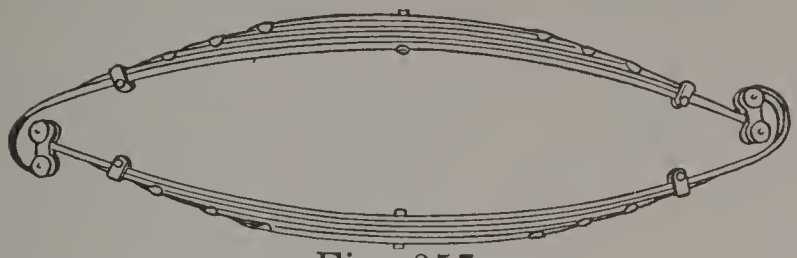


Fig. 257
Full Elliptic Spring, Scroll Ends

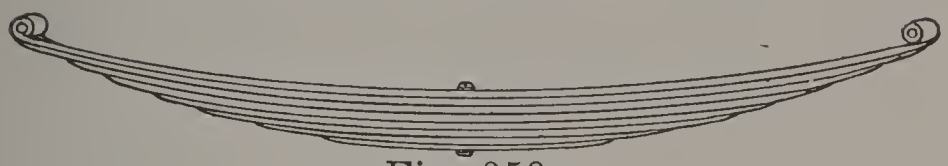


Fig. 258
Semi or Half-Elliptic Spring

Fig. 259
Three Quarter Elliptic Spring

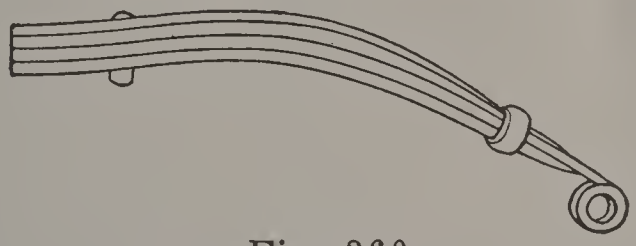


Fig. 260
Fixed Cantilever Spring

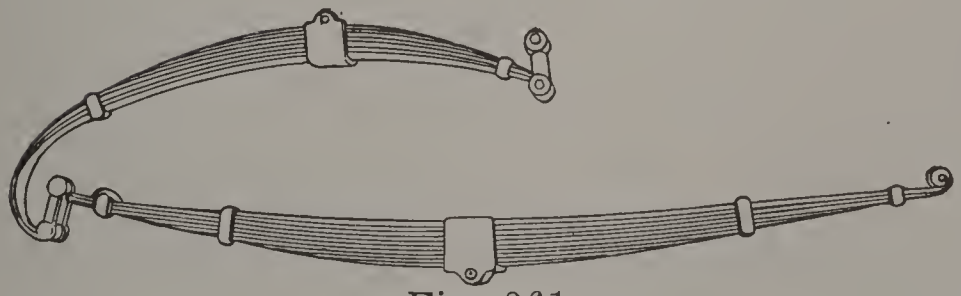


Fig. 261
Three Quarter Floating Cantilever Spring

for the bolt through the center of the spring is made larger than necessary.

Springs—Dimensions of. In calculating the dimensions and elastic limit of springs for motor-car use, the elastic limit must be carefully considered with regard to the dead, and maximum loads to be carried by the car. The dead load is the weight of the car when at rest. The maximum load is the greatest weight that can possibly be carried with good spring action. The springs to retain their elasticity should have their ultimate strength far beyond their maximum load capacity.

The old practice of fixing a uniform curvature of the spring leaves frequently leads to breakages due to distortions set up at the spring perch. This tendency is now aborted by making the spring leaves in such a way that the curvature begins at points beyond the spring perch, so that the clamps when they are pulled into tight relation do not straighten out the plates. It is still the custom to use a leather pad on which to rest the springs, because thereby the coefficient of friction becomes that of leather, and creeping tendencies are as a consequence remote. There is also the question of the camber given to the respective spring plates. If the plates are all of the same thickness, they should all be curved to the same radius, for then the extreme fiber strain would be equal in all the plates for every alteration in camber in-

cidental to the service they are placed to perform.

Springs—Testing and Material. The life of a spring is forecast by the maker thereof, almost independently of the quality of the material. If the spring is limber, and it is so placed as to indicate spring play, just at the point of reversals of camber, the life will be shortened. The superior grades of materials will stand this abuse for a comparatively long time, but the dynamic life of steel, like the life of every other animated thing, is limited. Inferior materials, advantageously situated, might last far longer than the superior products working at a disadvantage. The initial camber to give a spring, for a given static camber, is a problem for the springmaker.

Fig. 262 shows three views of a given spring, under the conditions as follows: The spring under static load, indicating the static camber; straightened out under load; in reverse camber, in a testing machine, to the limit before permanent set.

It is worth while to study these three conditions in relation to springs, because they have to do with the life of the spring in service, and the easy riding qualities of the car due to spring action. It might be said in general that the greater the difference between the initial and the static camber, the more pronounced will be the easy riding qualities, and it might be said as well that the greater the initial camber, and

the greater the possible reverse camber, the better will be the life of the springs, especially if we take into account that the spring action in service will be limited between the two points, as represented by the initial camber on the one hand and the condition, which means that the spring leaves will no more than straighten out in actual service. If the service conditions are such as to eliminate any reversal of camber,

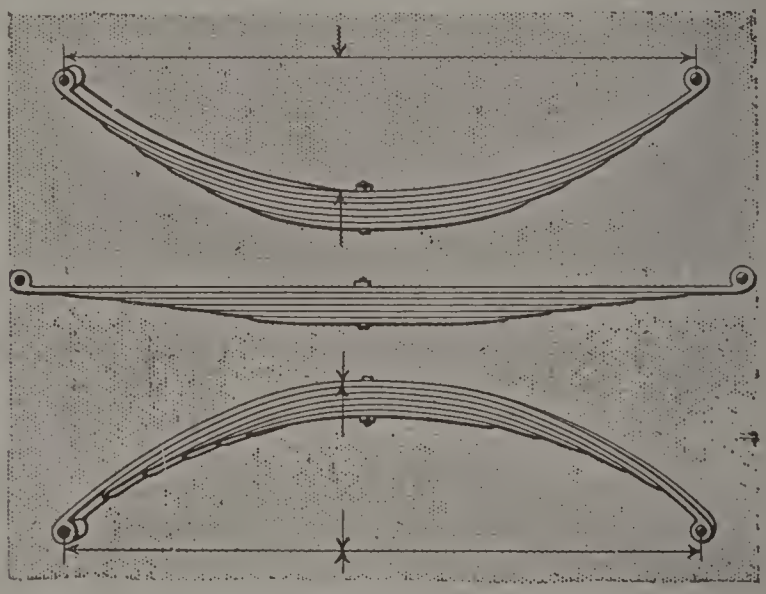



Fig. 262

then it may be said the factor of safety will be represented by the amount of the reverse camber in a testing machine before permanent set.

Springs—Care of. Springs should be examined occasionally, and while often overlooked, this seemingly trifling matter has a direct bearing upon the smooth, easy running of the car. Owing to the fact that the springs are exposed to the weather, rust is very likely to occur at

this point, and to this unsuspected corrosion is often due the occasional "squeak." Although many cars are provided with some means for lubricating the friction surfaces, many cars are not so well provided for and when rust makes its appearance along the joints there is a crying need for oil. This may be conveniently applied by placing the jack between spring and frame, and slightly opening the leaves or plates.

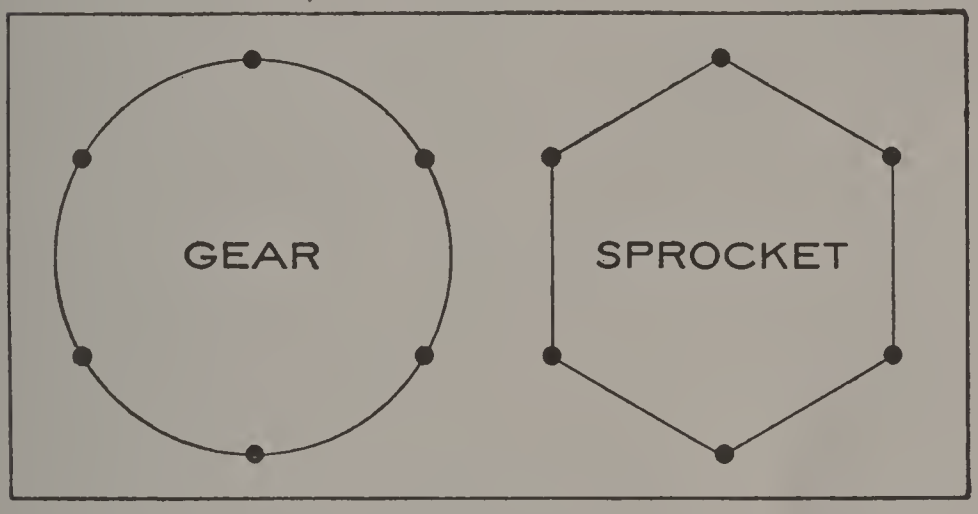


Fig. 263

The toggles and links should also have a little oil occasionally and when about this work it is well to examine the nuts of the clips. These nuts are prone to work loose.

Sprockets. The circular instead of the linear pitch is often erroneously used in calculating the pitch diameter of a sprocket wheel. Reference to Figure 263 will illustrate the difference between circular and linear pitch, and help to demonstrate the case more clearly. The view at the left of the drawing shows the circular pitch,

and the view at the right the linear pitch of a gear or sprocket wheel respectively. If the circular pitch of the gear be one inch and the gear has six teeth as shown, the pitch diameter will be 6×0.3183, which gives 1.91 inches as the pitch diameter. Let the linear pitch of the sprocket be also one inch, and with six teeth as before. In a sprocket having 6 teeth, the radius is equal to the linear pitch, as the figure is composed of six equilateral triangles, and the pitch diameter of the sprocket wheel is consequently 2 inches.

The pitch of the sprocket must, of course, be the same as that of the chain to be used with it. Chain pitches usually measure in even inches and common fractions. The type of chain, whether roller, block or silent, must also be considered. It is not safe to use mismated chains and sprockets.

Sprockets, Dimensions of. Table 11 gives the pitch diameters of sprockets for roller chain of 1 inch, 1¼ inch and 1½ inch pitch, with 7 to 28 teeth. The outside diameters may be found by adding the diameter of the roller to the pitch diameter of the sprocket.

Sprocket Chain Lubrication. The best lubricant for sprocket chains is a constant puzzle. If oil is used it is absorbed by the dust which settles on the chain. If tallow or other animal grease is employed it is pushed away from the bearing surfaces, and the latter get dry. The ideal lubricant would seem to be something be-

TABLE 11.

DIMENSIONS OF SPROCKETS FOR ROLLER CHAIN.

Number of Teeth in Sprocket.	1 Inch Pitch.	1¼ Inch Pitch.	1½ Inch Pitch.
	Pitch Dia.	Pitch Dia.	Pitch Dia.
7	2.31	2.88	3.46
8	2.61	3.27	3.92
9	2.92	3.65	4.38
10	3.24	4.04	4.85
11	3.54	4.44	5.33
12	3.86	4.83	5.79
13	4.18	5.22	6.27
14	4.50	5.62	6.75
15	4.81	6.01	7.22
16	5.12	6.41	7.69
18	5.76	6.41	8.64
20	6.39	7.99	9.59
22	7.03	8.79	10.55
24	7.66	9.58	11.49
26	8.31	10.38	12.44
28	8.95	11.19	13.42

tween an oil and a grease, too thick to be drawn out by absorption, yet soft enough and clinging enough to stay in the rollers. This mission is approximately fulfilled by a mineral grease, such as non-fluid oil, or Keystone grease, which are not affected by moderate changes of temperature, and have the clinging quality which animal greases lack. The makers of these greases, however, do not recommend heating them, and they cannot be introduced into the links and rollers of the chains, except by rendering them temporarily more fluid than they are desired to be in service. A very good lubricant for this purpose is made by dissolving Keystone grease in gear case oil, in amounts sufficient to produce a viscous fluid at the boiling

point, which thickened when cold, and would just barely flow. A fairly liberal quantity of graphite was added, about half a cupful to three quarts of dope, and the chains after cleaning were boiled for half an hour or longer in the mixture to enable it to penetrate thoroughly.

Starting and Lighting Systems.

Four principal types of engine starters have been used; the air starter, the mechanical starter, the acetylene starter and the electric starter. Beginning with the production of 1916 cars, the electric starter is the only one found as standard equipment.

Acetylene starters were used by many cars in 1913. This form admits acetylene gas from the lighting tank to the cylinder that is ready to fire through a distributor valve. The passage of an ignition spark caused by operating a button on the dash fires the gas and the force of the explosion starts the engine.

Mechanical starters are found in many forms. They consist of a mechanism through which the driver is enabled to turn the engine crankshaft through connections that lead to a handle or lever that may be reached from the seat.

Compressed Air Starters. In a typical air-pressure system the motor is operated with compressed air until regular explosions take place in the cylinders; the air supply is then shut off and the motor takes up its regular operations.

The parts of this self-starter are as follows (see Fig. 264): 1, a high-pressure, four-cylinder air pump, for compressing air in a storage tank; 2, a pipe for carrying air from pump to storage tank; 3, a pipe which carries air from

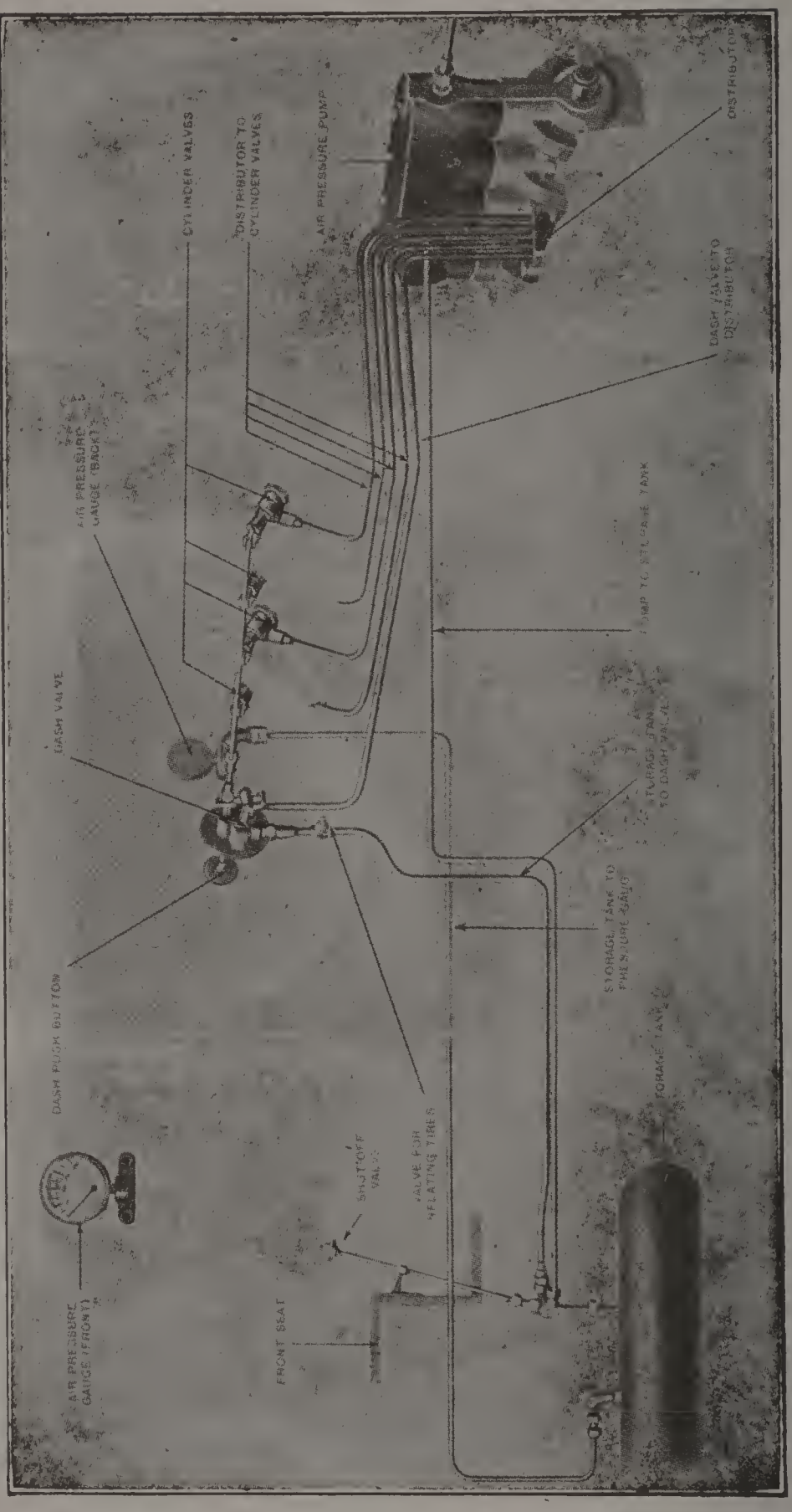


Fig. 264.—Chalmers Air Pressure Starting Mechanism.

tank to push valve on the dash; 4, a pipe which carries compressed air from the push valve to the "distributor"; 5, pipes through which air is carried from the distributor to the various cylinders; 6, poppet valves—one in each of the cylinders—by means of which compressed air from the distributor is admitted to the cylinder ready for the working stroke; 7, a pressure gauge on the dash, which keeps the operator informed of the amount of compressed air in the storage tank; and 8, a pump clutch, operated by a foot pedal, which throws the gears of the air pump into mesh.

The air pump in this system is driven by a silent drive chain from the water pump shaft, and operates only when the gears are thrown into mesh by pressing the pump clutch foot pedal. It is a simple device for compressing the air and delivers a steady flow to the storage tank. A pressure of 50 lbs. in the tank will start the motor under ordinary conditions, but it is advisable to keep the pressure at about 150 lbs.

The storage tank is carried beneath the body of the car and is tested for a pressure of 600 lbs. to the square inch.

The dash push valve opens the air line from the storage tank to the distributor and simultaneously opens the cylinder valves so that air coming from the distributor through the pipes shown in Fig. 264 has ready access to the cylinders. When the foot is removed from the

dash button, both the escapement valve and the cylinder valves are closed automatically and the compressed-air starter is shut off from the motor.

The distributor sends charges of compressed air into the cylinders ready for the working stroke, in their order of firing. It is geared to the pump and magneto shaft and positively timed for feeding air.

This type of self-starter is also used for the purpose of inflating tires by means of a special shut-off valve and hose.

The principle of compressed-air starters is to admit air under 50 to 150 lbs. pressure from a generous reservoir directly to the motor cylinders at the beginning of each expansion stroke. This operates the motor without affecting the mixture in the cylinders. When running under air pressure the admission of the compressed air at almost the moment of the spark operates the same as an ignition, causing a rise of pressure in the cylinder. After it has performed its work this pressure is released by the exhaust valve in the same manner as the burned gases are released when the motor is running under its own power.

Allis-Chalmers Equipment. The most commonly used type of Allis-Chalmers equipment makes use of a combined motor-dynamo, Fig.

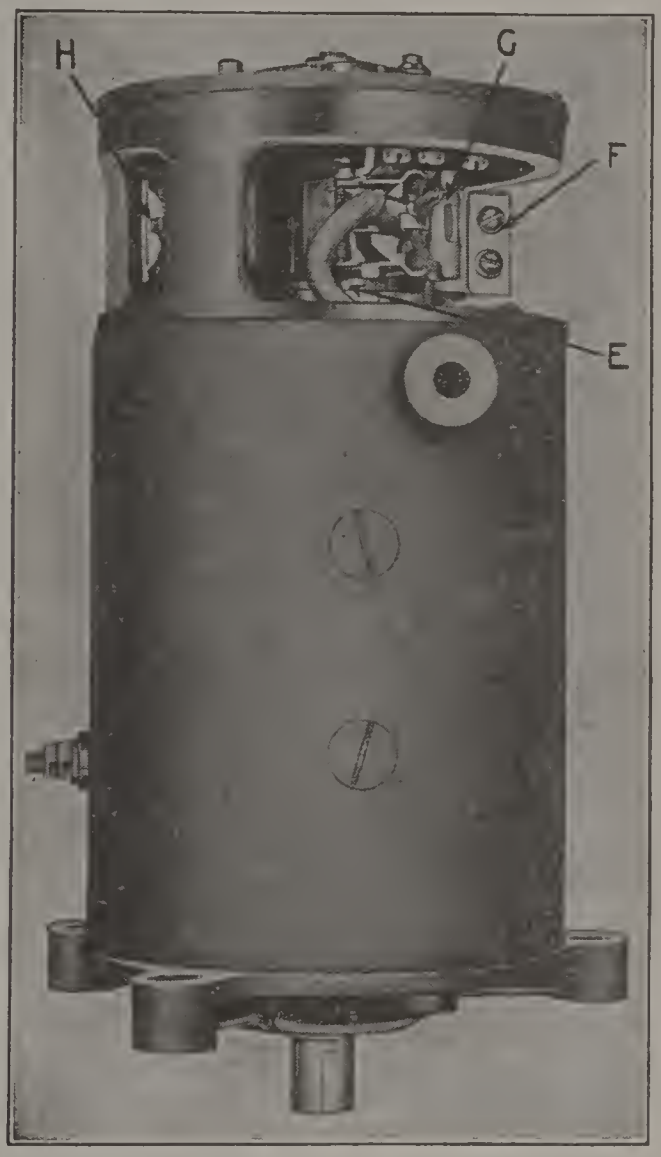


Fig. 265

Allis-Chalmers Motor-Dynamo. E, Commutator. F, Brush Holder. G, Brush Connection. H, Brush Connection.

265, operating at six volts pressure for starting, charging and lighting. In addition to the motor-dynamo, the system includes the battery, a start-

ing switch and a separately mounted combined cut-out and regulator.

Pushing the starting switch connects the battery with the motor-dynamo, which then operates as a motor to crank the engine to which it is mechanically connected. The switch is then released after the engine fires. The motor-dynamo speeds up with the engine and, when it reaches a certain predetermined speed, is automatically connected to the battery and the lighting system by means of the cut-out. If the lights are burning, part of the current is used in lighting, the surplus going to charge the battery. When the engine slows down below the charging speed, the cut-out opens the circuit between the generator and battery.

By removing the cover band, the commutator may be examined. When in good condition it will show a glaze and will be dark brown in color. If the commutator appears dirty or greasy it should be wiped off with a clean cloth free from lint, slightly moistened with oil.

Do not disturb the brushes so long as the motor-generator appears to be operating properly. They should make good contact with the commutator and slide smoothly in the brush holders.

The purpose of the combined cut-out and regulator is to connect the generator to the battery when its voltage equals that of the battery, and to maintain a practically constant charging current with the widely varying speeds of the en-

gine. It also disconnects the battery when the motor-generator voltage falls below that of the battery, preventing the battery from discharging.

The regulator-cutout consists of a compound wound electromagnet with two armatures, one of which serves as the cut-out while the other regulates the charging current. The shunt regulator winding is always connected across the generator terminals. When the generator voltage is sufficient for charging, the electromagnet attracts the armature, closing the circuit through the series coil of the regulator of the battery. The current flowing in the series coil then assists the shunt coil to hold the contacts together. With an increase in generator speed, the charging current will increase, strengthening the regulator electromagnet. At a certain critical point the second armature will vibrate, alternately cutting a resistance in and out of the generator field circuit, which will reduce the charging current by lowering the generated voltage. When the generator speed, and consequently the voltage, drops below charging value the reverse battery current flowing in the series winding neutralizes the shunt winding, releasing the armature and thus opening the circuit before the battery can discharge.

The internal connections and mechanism of the regulator-cutout are shown in the diagram, Fig. 266.

The regulator is provided with a fuse to pro-

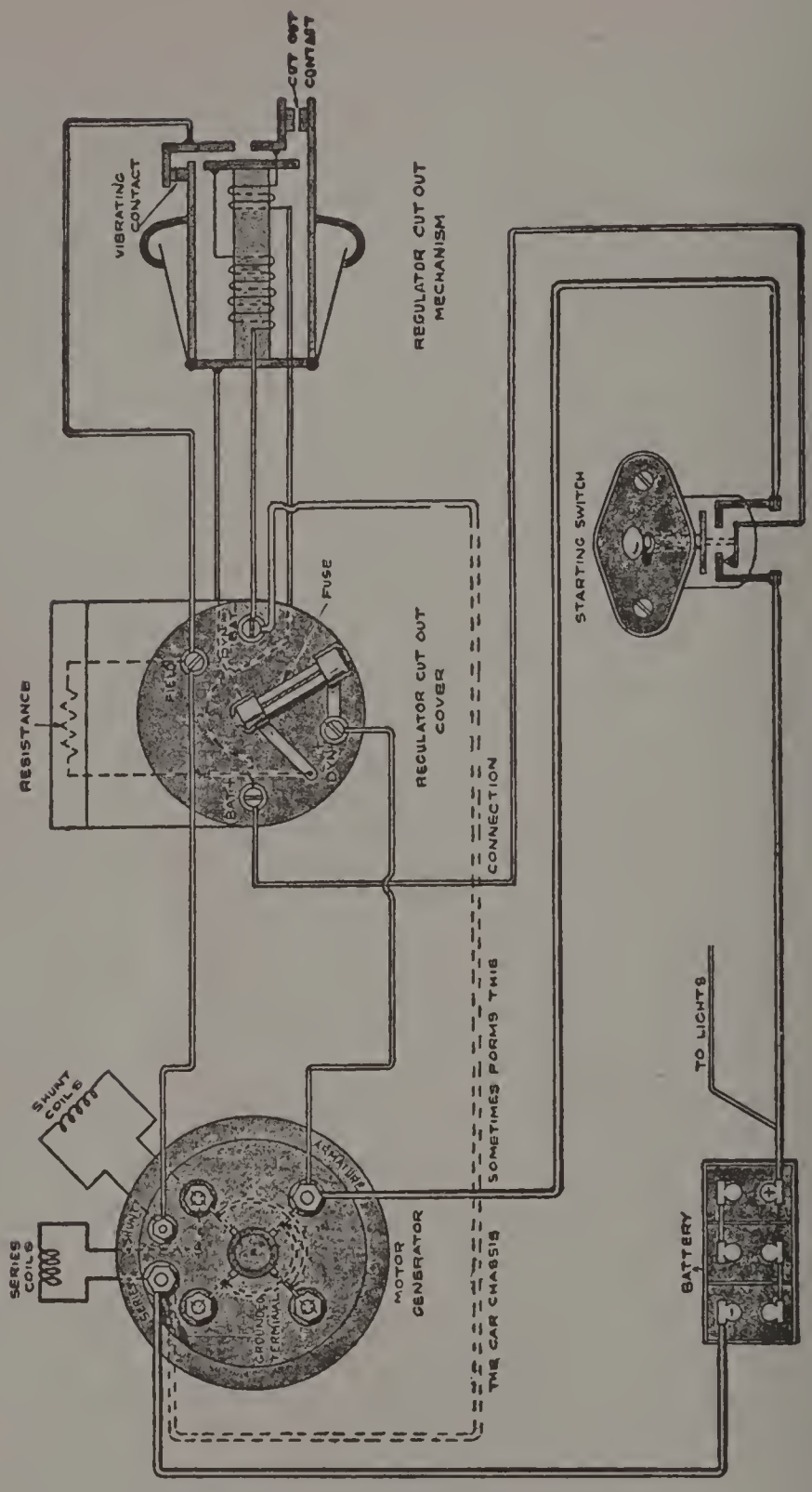


Fig. 266
Allis-Chalmers Motor-Dynamo Internal Connections

tect the system from excessive charging current, or an improper discharge through the starter, in case the regulator should not function properly. This fuse has a capacity of 45 amperes and carries the shunt field current as well as the battery charging current. The fuse, which is made of an especially hard alloy to withstand the high temperature near the engine, should always be replaced by one of the same make. If several fuses are blown within a short time, the regulator is probably out of order and should be replaced. This fuse does not protect the lighting and horn circuits.

To prove whether the motor-dynamo is charging the battery or not, remove the wire from the "BAT.+" terminal of the regulator and insert an ammeter between this terminal and the wire, with the positive terminal of the meter connected to the terminal of the regulator. With the engine running at about 60 revolutions per minute or higher, the meter should show a charging current of 10 to 18 amperes. If the meter shows no current, the motor-dynamo is either not developing any voltage or there is an open circuit in the charging line. To determine whether the motor-dynamo is developing any voltage, open the circuit at ammeter and then remove the wire from the "F L D" terminal of the regulator. With the engine still running as above, there should be quite a flash on removing the wire from the "F L D" terminal of the regulator. All these tests are to be made

with a good fuse in place on the regulator. If no flash is obtained on removing the wire from the "F L D" terminal, hold the wire on the fuse clip for a few seconds and note whether there is a flash on removing it. A flash here and none from the "F L D" terminal indicates a fault in the regulator. No flash from the fuse clip indicates a fault in the motor-generator. It is assumed here that the connections between the regulator and the motor-dynamo have been examined and found correct and sound.

If the motor-dynamo develops its voltage but still does not charge the battery, the fault is either in the regulator or the auxiliary contact of the starting switch. This can be located by connecting up the ammeter again as before, and with the engine still running hold a wire pumper in the hands and first connect the "DYN+" terminal of the regulator to the "BAT+" terminal. If the battery now charges, the fault is in the regulator. If no result is obtained, connect "BAT+" terminal of the regulator to the positive terminal of the battery. The charging of the battery now would indicate that the fault was in the starting switch.

The motor-dynamo should not be run with the charging circuit open, except for a minute or two at a time in making tests and not at all at very high speeds, as it would damage both the motor-dynamo and the regulator, and also the lights if turned on. If it is necessary to operate the car with the battery removed or with the

battery circuit open in any way, so that it cannot charge, the fuse must be removed from its place on the regulator.

Auto-Lite Equipment. These systems consist of separate unit dynamos and starting motors operating with a six-volt pressure in all

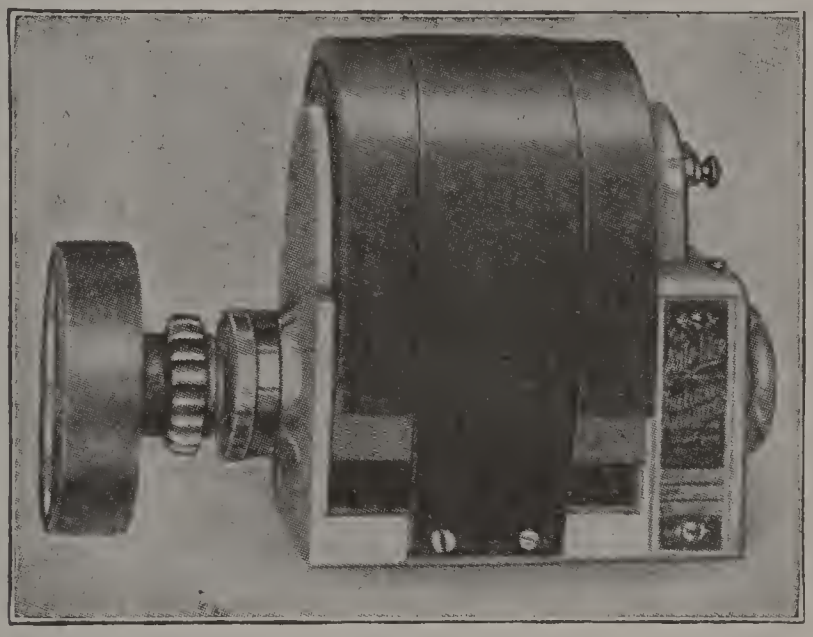


Fig. 267
Auto-Lite Dynamo With Permanent Field Magnets and Clutch Governor

cases. The first models were of the permanent magnet type, that is to say, the dynamo field consisted of six powerful steel magnets without the usual coils, Fig. 267. These magnets were of the inverted U, or horseshoe, type, and underneath the arch thus formed was mounted an electromagnetic cut-out which closes the charging circuit whenever the dynamo voltage is suffi-

ciently high to charge the battery. This part of the mechanism may be exposed by removing the brush wires and taking out the plate that carries the positive and negative dynamo terminals.

This permanent magnet dynamo is driven from the engine by silent chain, but between the chain sprocket and the dynamo armature shaft is a form of slipping clutch governor contained in the drum seen at the left hand end of Fig. 267. The shell of this drum has its driving connection to the shaft by means of two shoes that are pressed outward by springs. Two weights are carried at or near the ends of corresponding arms inside of the drum, and when the armature shaft has reached a certain predetermined speed the centrifugal action of the weights overcomes the tension of the springs and the shoes release their hold on the shell. By thus preventing an armature speed above the desired maximum, the voltage and output of the dynamo is held at a point suitable for battery charging.

A later form of Auto-Lite dynamo is shown in Fig. 268. This model retains the inverted U form of field magnet cores, but around the top of the magnet arch is placed a field coil housing and in this housing is a shunt and a reversed series field winding. The shunt field winding is attached between the brushes in the usual way, and the entire dynamo output passes out through the reversed series winding. This series winding being placed in such a way that

it opposes the action of the shunt, dynamo output above a certain point is made to overcome the field magnetism to such an extent that the amperage shows no further rise. The two dynamo terminals are seen on the front of the field housing and with this machine the electromagnetic cut-out is separately mounted, usually on the dash of the car.

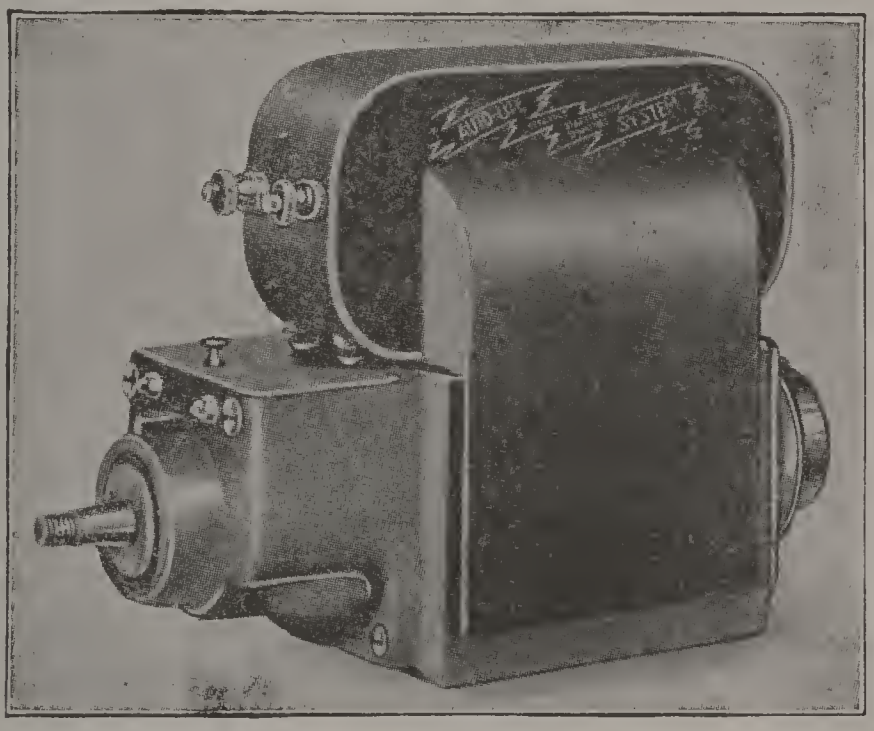


Fig. 268
Auto-Lite Dynamo With Electromagnetic Fields

A third type of Auto-Lite dynamo is shown in Fig. 269. This machine is fully enclosed and has its fields placed above and below the armature. The field windings and regulation of output by means of the reversed series coil is the

same as in the type just described. The brushes and commutator may be exposed by removing the plate A.

Bijur Equipment. These systems are made in three distinct forms, two being six-volt separate unit dynamo and starting motor types, while the third is a combined motor-dynamo operating at twelve volts for both charging and starting.

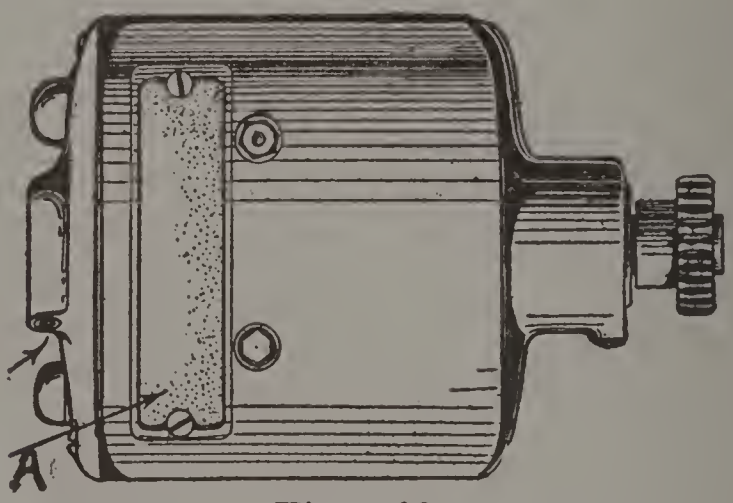


Fig. 269
Auto-Lite Fully Enclosed Dynamo.

One of the six-volt systems makes use of a straight shunt-wound dynamo having a combined regulator and cut-out mounted in an aluminum housing on top of the dynamo case. Connected in series with the shunt winding is a coil of high resistance wire which is automatically inserted in the shunt field circuit by the regulator, this action keeping the voltage constant. The regulator consists of an electromagnet with its winding shunted across the

brushes, so that current always flows around the magnet when the dynamo runs, also the regulator contacts which are connected to carry the shunt field current around the resistance coil when they are closed. As the dynamo voltage rises, the magnet pulls the armature against the small spring and opens the contacts. The shunt field current then flows through the resistance and is so reduced that the field strength and voltage immediately fall. The low voltage reduces the strength of the electromagnet and the spring again closes the contacts, allowing the field current to avoid the resistance coil and raise the voltage. The regulator contacts vibrate this way at the rate of about 100 times a second and this holds the voltage at a point determined by the strength of the regulator spring or its tension.

The cut-out is electromagnetic with two windings and is carried in the same case with the regulator, this case being on top of the dynamo. All connections between dynamo, regulator and cut-out are made between the regulator housing and dynamo case and are not exposed. Two wires only come from the dynamo, one positive and one negative.

The dynamo wires end in a brass plug on one end of the regulator case. This plug may be rotated in its socket so that it makes part of a turn one way or the other. Turning this plug as far toward the engine as it will go makes one wire positive and the other negative, and turn-

ing it as far from the engine as it will go reverses this polarity. This reversal should be made every 500 miles, being sure that the plug is turned as far as it will go so that it locks in place. This action reverses the polarity of the dynamo and prevents pitting of the contacts.

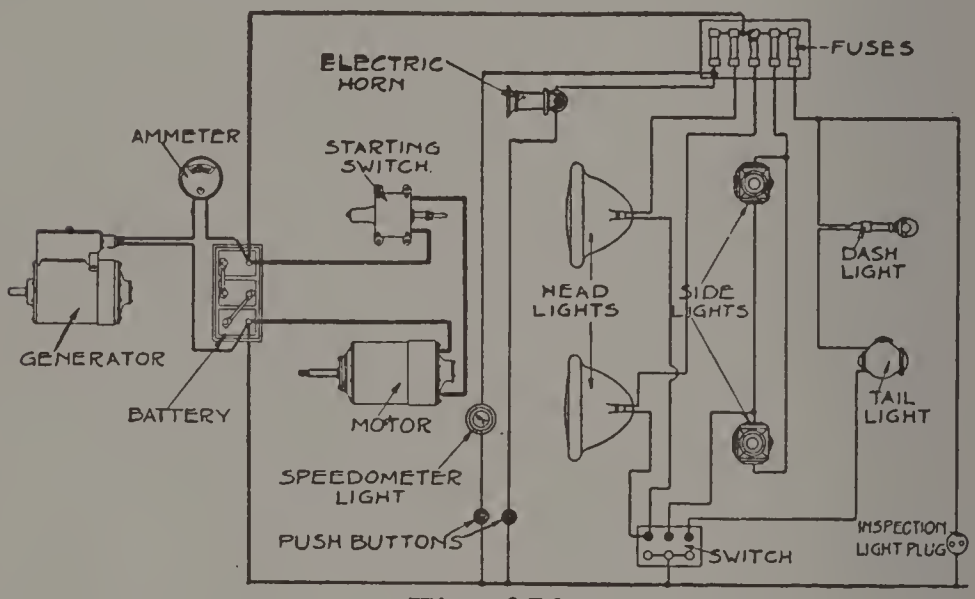


Fig. 270

Bijur Wiring Diagram for Voltage Control System

After adjustments are made the regulator box is sealed at the factory and the maker's instructions say not to open it. The entire box may be removed from the dynamo by unscrewing the small milled nut on top, the connections between the cases being made with split pins. Lights and starter will run from the battery while the regulator is returned to the makers for repairs. A complete wiring diagram for this form of Bijur apparatus is shown in Fig. 270.

In Fig. 271 is shown the application of another form of six-volt separate unit system.

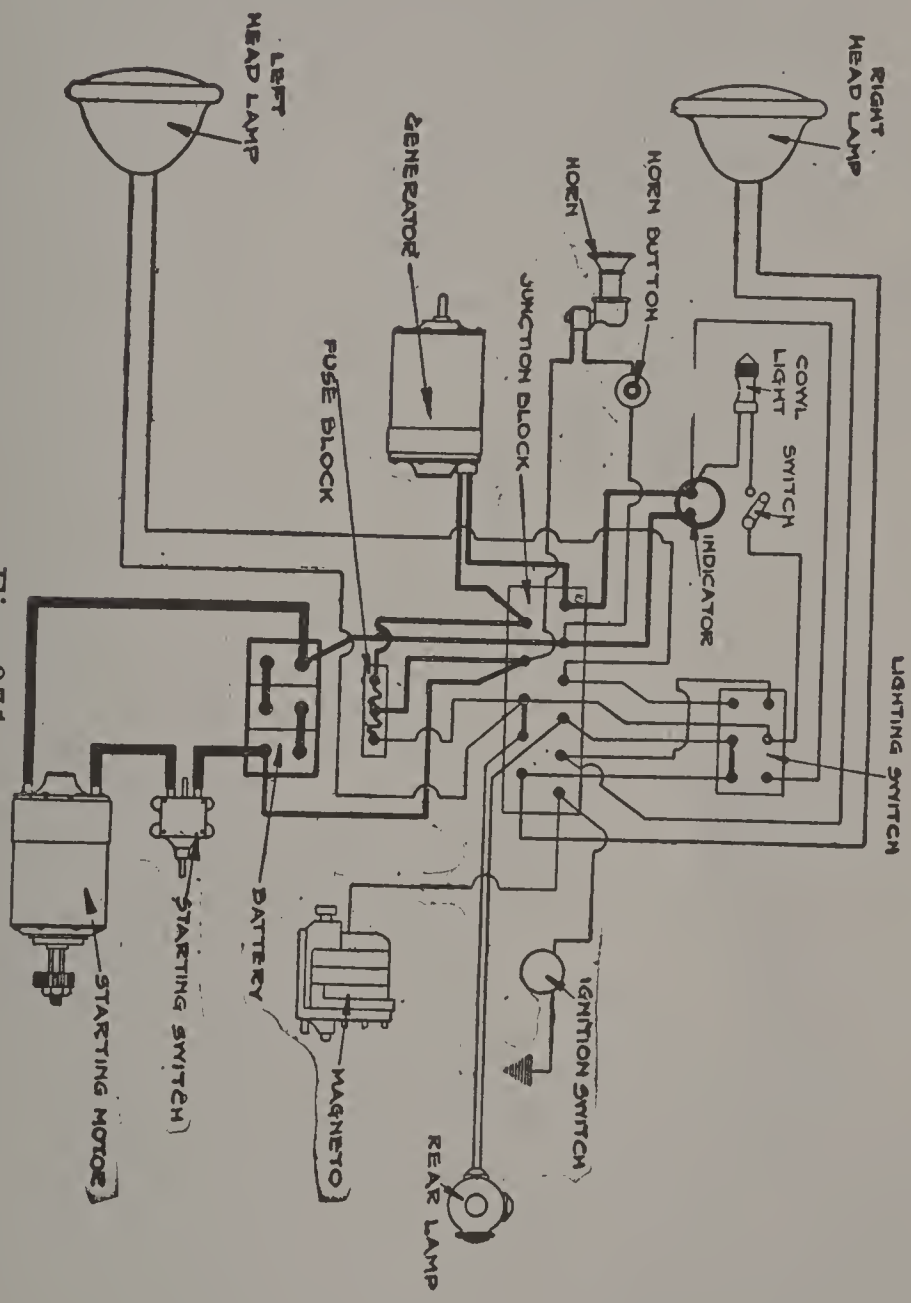


Fig. 271

Bijur Wiring Diagram for Third Brush Dynamo

This dynamo has no controller box as has the one just described, but the shunt field winding

is connected to an additional brush bearing on the dynamo commutator. This brush is for the purpose of limiting the dynamo amperage and is so placed in relation to the main brushes that the current passing into it, and thereby into the shunt field, diminishes with increase of speed. The normal tendency of the output to increase with the speed of rotation is therefore counteracted and a safe maximum is maintained. This is the form of regulation known as "third brush."

The electromagnetic cut-out for this system is mounted inside of the brush and commutator end of the dynamo case. This end of the machine is closed by a removable brass band, and through the openings left with this band removed the working parts of the machine may be inspected. Mounted on the outside of the dynamo case, and connected in series with the field windings, is a small fuse which will blow out whenever the current passing through the fields becomes excessive. This fuse will protect the dynamo in case of a broken circuit between dynamo and battery or lamp lines.

Separate starting motors of Bijur make may drive to the engine through an overrunning clutch, through direct acting spur gears or by means of a Bendix screw. With the Bendix screw, a single contact starting switch is used which sends the full battery current to the motor when the switch is closed. With the spur gear drive, the starter switch makes a preliminary

contact through a resistance coil and continued movement of the switch pedal and plunger closes the contacts that short circuit the resistance and send the full battery current through the motor. The same operation that meshes the starting gears moves the switch plunger.

Bijur motor-dynamos operate at twelve volts and have their output controlled by the "third brush" system as explained for the type just described. Drive is direct to the engine crankshaft through a silent chain. No cut-out is used, but when the motor-dynamo is connected to the battery by means of the starting switch, the switch is allowed to remain closed and the increasing speed of the unit when driven from the engine causes the voltage as a dynamo to rise to a point that recharges the battery. When the car is operated at a speed below about ten miles an hour, the dynamo voltage falls below that of a battery and the unit again becomes a starting motor. A neutral position is provided on the starting switch for use when the car is being driven at low speeds or when the engine is idling. With the switch in this position the motor-dynamo is disconnected and battery discharge is prevented.

Bosch Equipment. The dynamo is shown in Fig. 272 and is used in connection with a starting motor of the Rushmore type and having the Rushmore form of drive to the flywheel.

The dynamo is a separate unit, shunt wound, delivering 12 volts with a maximum output of

8 to 10 amperes at high car speeds with a partially discharged battery.

A box mounted on the dash carries a volt-ammeter, voltage regulator, cut-out, lighting and ignition switches and fuses. A small lever is moved to cause the meter to show either volts or amperes on the same meter.

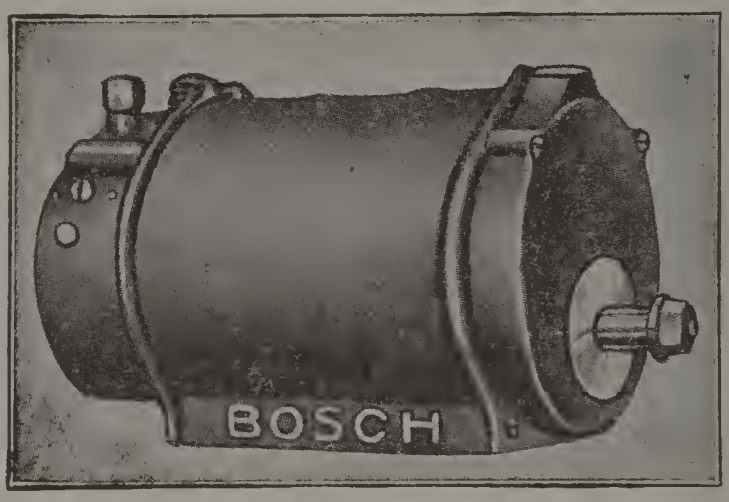


Fig. 272
Bosch Dynamo

Regulation acts to maintain a steady voltage. The regulator consists of a small cylinder of carbon particles with one end of the shunt field winding connected to one end of the carbon pile and the corresponding dynamo brush connected to the other end of the carbon. The shunt field current thus passes through the carbon. The carbon particles are held tightly compressed by a plunger fitting inside the cylinder with a coil spring holding the plunger down. Under this condition the resistance of the carbon is very low and allows practically the whole of the

shunt field current to pass without interruption. An electromagnet forms part of the regulator and is connected in shunt across the dynamo brushes so that its strength increases with the rise in voltage. This electromagnet acts to pull up on the plunger against the action of the spring, and as the voltage rises the pressure on the carbon is lessened in this way and the resistance of the carbon pile increases rapidly as the particles are loosened. This resistance in the field lowers the voltage and output.

An electromagnetic cut-out is carried in the dash unit housing with the voltage regulator. These systems make use of the single wire, ground return method of wiring. The starting cable is, however, covered with a copper sheath that assists in carrying the return current to the battery.

Delco Equipment. A majority of Delco applications have been of the motor-dynamo type, this method being departed from for the first time on some of the applications made on 1916 cars. The first Delco system to be used consisted of a motor-dynamo that operated as a starter at 24 volts and charged to six volts for lighting and battery charging. The battery for this system consists of twelve cells divided into four sections of three cells each. By means of a two position multiple contact knife switch carried in the battery box, these sections were placed in series for starting and in parallel for lighting and charging. The

complete charging circuit diagram is shown in Fig. 273.

The battery charge is controlled by a form of wattmeter, called an ampere-hour meter. Current flowing into the battery causes this meter to revolve in one direction and current

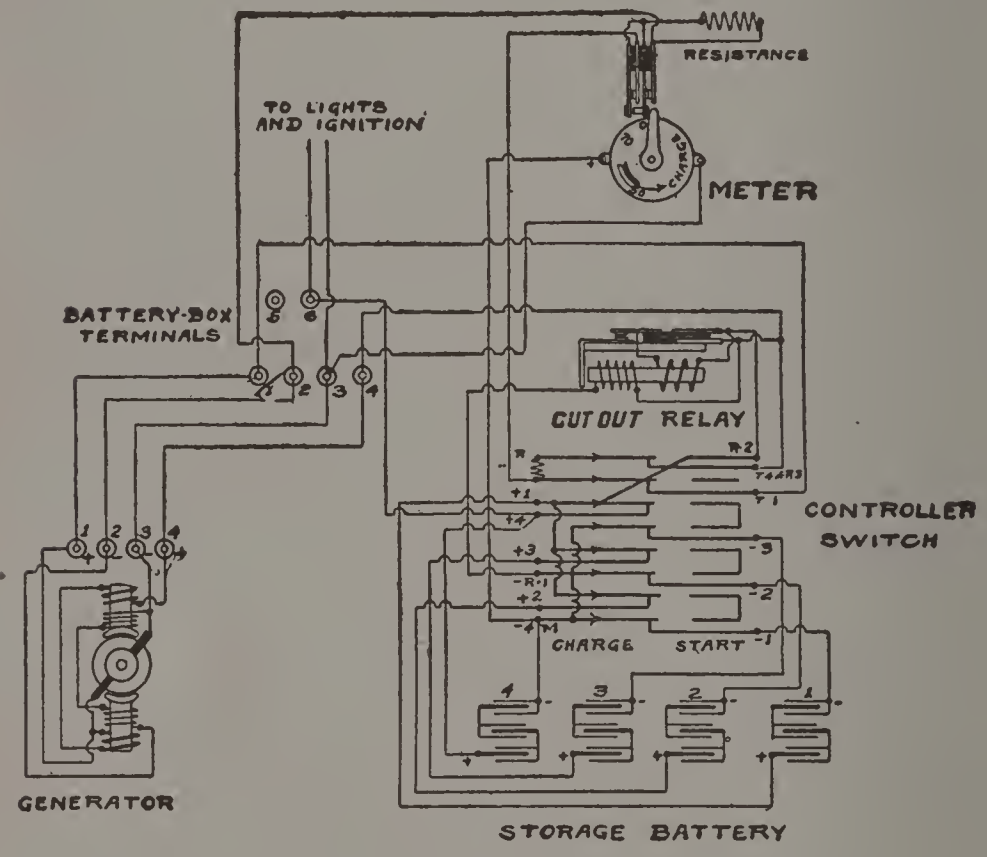


Fig. 273
Charging Circuit of Delco 6-24 Volt System

flowing out of the battery causes it to revolve in the opposite direction. After a certain flow has entered the battery, the meter has moved to such a position that a resistance is inserted in the shunt field winding of the dynamo and the rate of charge is thereby reduced. Further

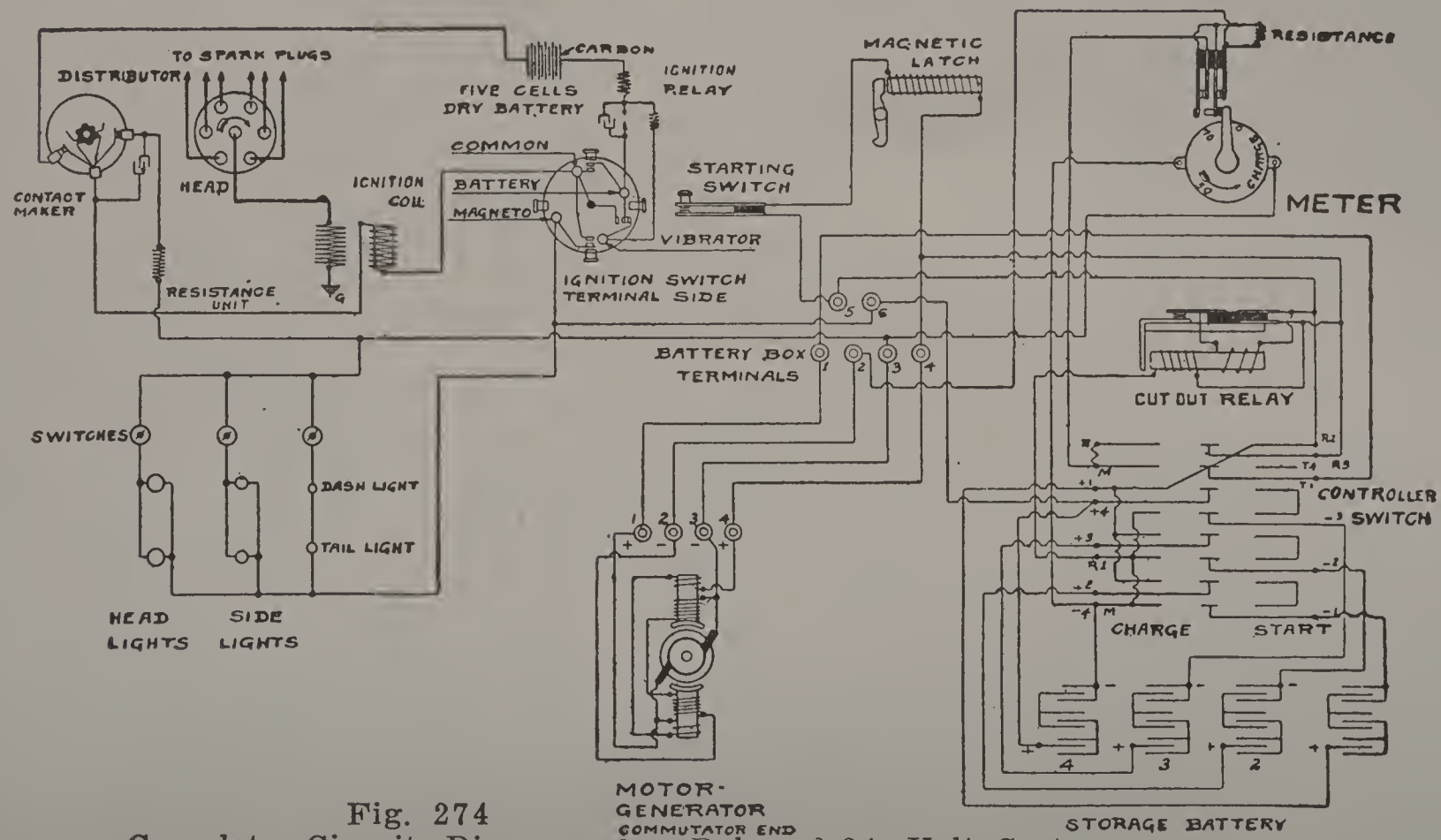


Fig. 274
Complete Circuit Diagram for Delco 6-24 Volt System

movement of the meter in the same direction opens the shunt field current and further battery charge is prevented. Withdrawal of current causes the meter to reverse this movement and the field circuit is first closed through the resistance and the resistance is then cut out entirely, allowing a resumption of full battery charge.

Fig. 274 shows the complete circuit diagram for this system. The magnetic latch is for the purpose of allowing the driver to close the starting switch and mesh the motor gears with the flywheel when the clutch pedal is depressed. By means of a small push button, usually on the heel board, the latch magnet is energized and the latch itself connects the starting gearing with the clutch pedal. Depression of the pedal then causes starting action as described. The application of this system on a car, with external wiring shown, is seen in Fig. 275.

A form of Delco motor-dynamo having two separate commutators and two sets of brushes is shown in Fig. 276. One of these commutators is for the dynamo generating action, while the other is for starting.

When the unit is generating current for charging the battery, for lights and ignition, it is a simple shunt wound generator. It is driven from the engine by an extension of the pump shaft. The generator is driven at one and one-half crankshaft speed, and in order to compensate for the higher ratio when the

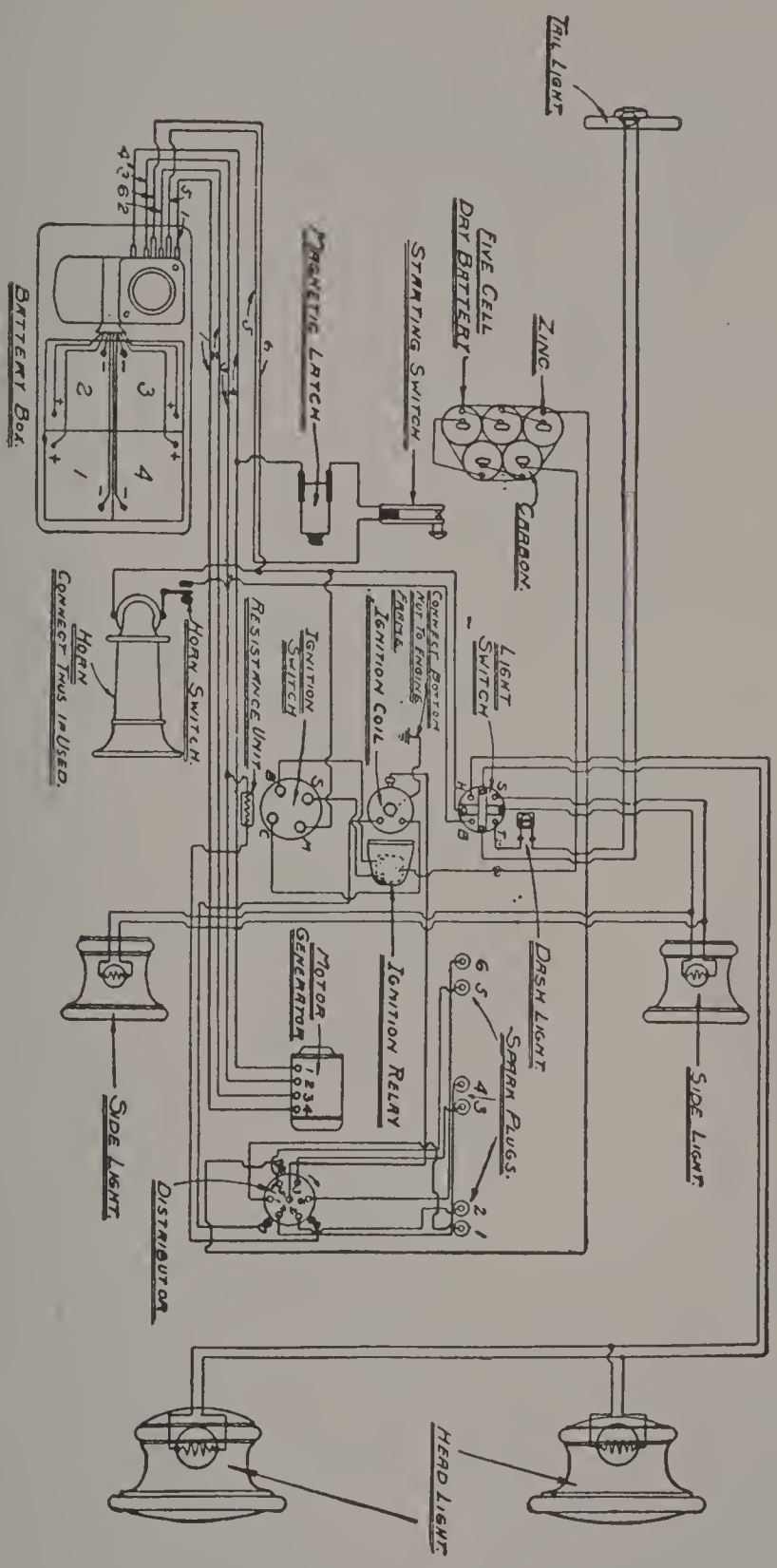


Fig. 275
Complete Car Wiring for Delco 6-24 Volt System

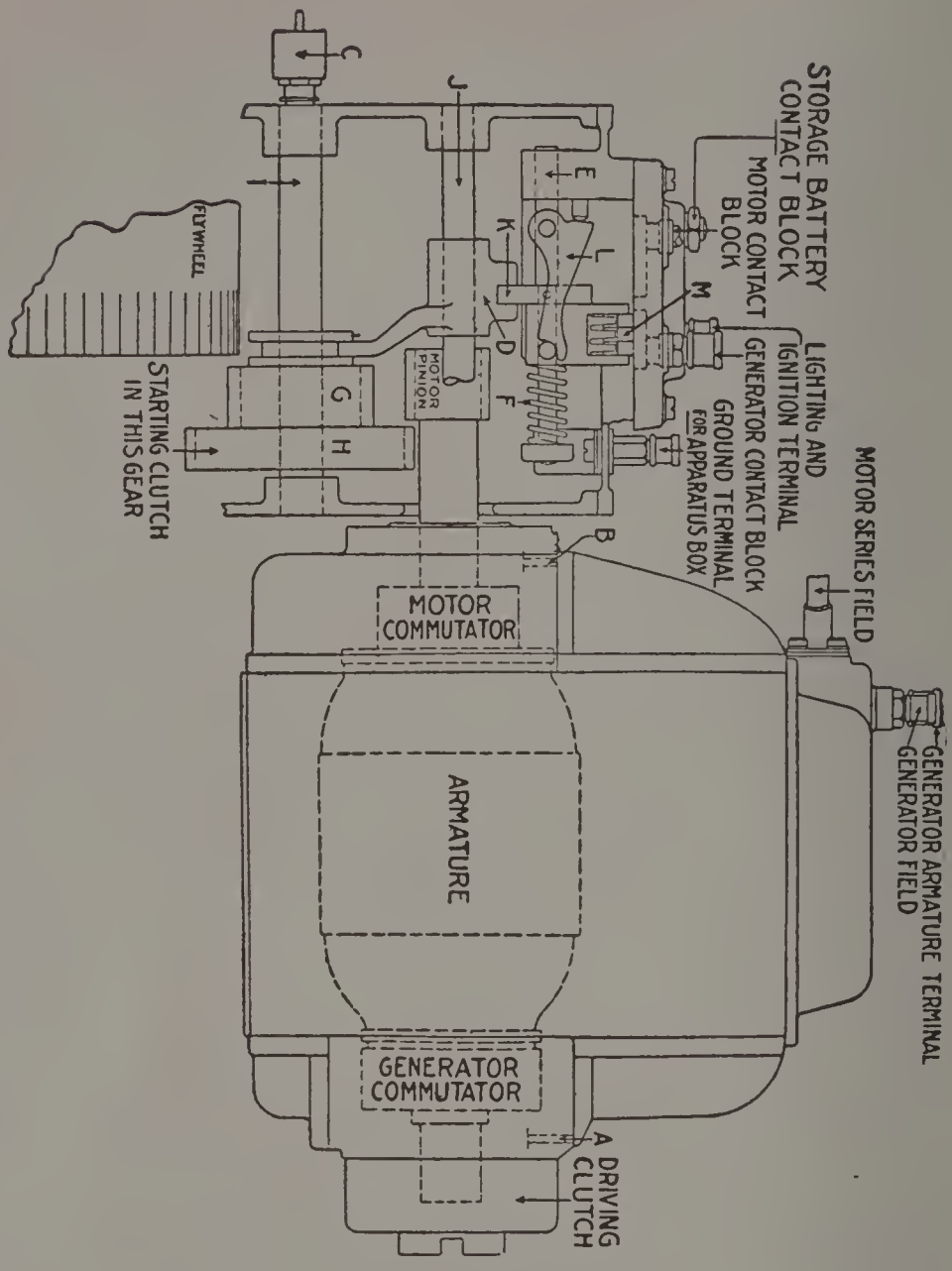


Fig. 276

Delco Motor-Dynamo With Starter Switch Mounted Above Flywheel Drive Gearing. A, Oil Hole. B, Oil Hole. C, Grease Cup. D, Gear Shift Yoke. E, Switch Operating Rod. F, Switch Spring. G, Flywheel Gear. H, Motor Pinion Gear. I, Clutch Shaft. J, Shift Yoke Rod. K, Tripping Collar. L, Contact Block Latch. M, Contact Block.

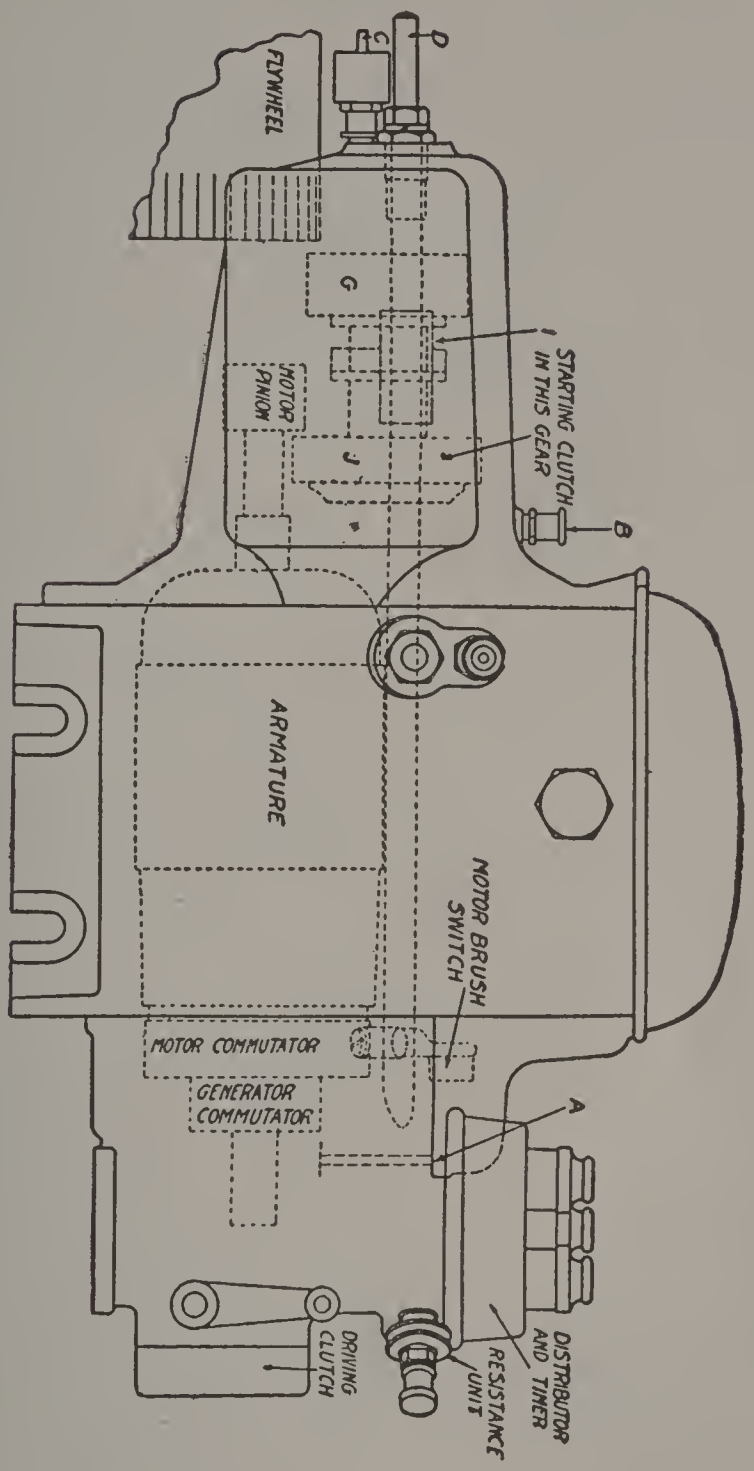


Fig. 277
Delco "Junior" Motor-Dynamo

unit is in starting relation to the engine, a second one-way clutch is provided adjacent to the forward housing. This clutch permits the armature to run ahead of the driving shaft during the cranking operation.

Fig. 277 illustrates the Delco "Junior" motor-dynamo and the starting switch is shown

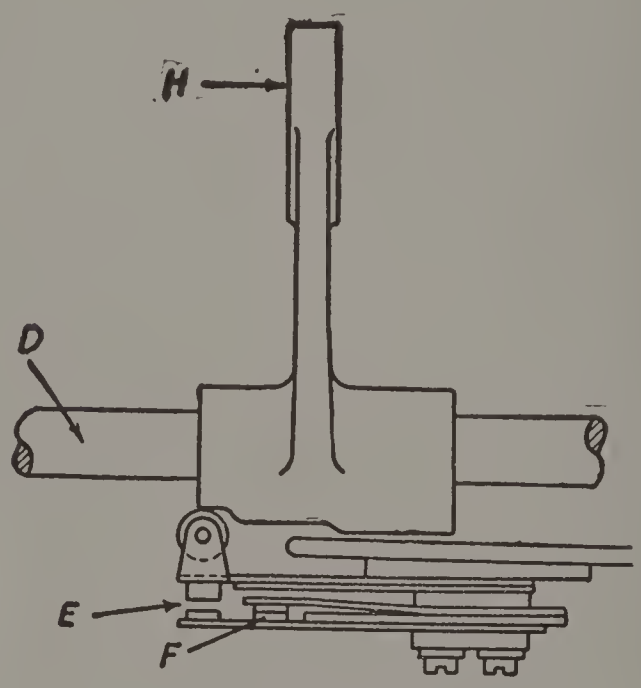


Fig. 278
Delco Starting Switch

in Fig. 278. These units cannot well be shown in their actual locations and are therefore shown separate. Referring to Figs. 277 and 278, the yoke H fits into the collar I which is pinned to the rod D. The movement of the rod from the starter pedal operates the gearing and the starting switch.

When the starting pedal is pushed down it pulls back the rod D and closes the contact E, which completes the circuit between the battery and dynamo armature. The closing of the circuit causes the armature to revolve slowly so that the gear J will mesh with the motor pinion as it slides along on its shaft. As the starting pedal is pushed further down it continues to pull the rod D, which opens the contact F, breaking the circuit between the battery and dynamo armature. This action of the rod at the same time causes the motor brush switch to drop onto the motor commutator, and the train of gears to slide on its shaft until in mesh with the motor pinion and the teeth on the flywheel.

The motor brush dropping on the commutator causes the circuit to be closed between the storage battery and the motor armature, which causes the motor to crank over the engine.

When the starting lever is released the motor switch brush is raised from the motor commutator and the train of gears is thrown out of mesh, when the contacts F will automatically close.

If the speed of the motor generator is above 350 revolutions per minute, the cut-out relay, Fig. 279, will close the circuit between the storage battery and motor generator, thus permitting the generator to charge the storage battery. If the speed of the motor generator is less than 350 revolutions per minute, the cut-out relay will remain open and all current for

ignition and lights, if they are in use, will come from the storage battery.

Oil is conveyed to the ball bearings through oil cup B and the small hole A in the front end cover. This hole is made accessible by removing the upper front end cover. At the time 4 or 5 drops of light oil are put in the oil cup B and the hole A, the grease cup C should be

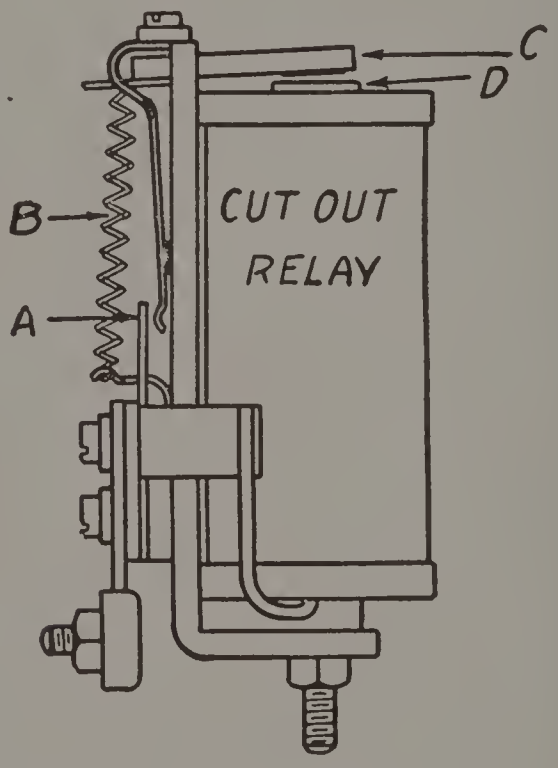


Fig. 279
Delco Reverse Current Cut-out

given 1 or 2 turns or replenished if empty.

The cut-out relay, Fig. 279, is located in the rear end housing of the generator. This instrument closes the circuit between the generator

and the storage battery when the generator voltage is high enough to charge the storage battery. It also opens the circuit as the generator slows down and its voltage becomes less than that of the storage battery, thus preventing the battery from discharging back through the generator. The cut-out relay is an electromagnet with a compound winding. The voltage coil or fine wire winding is connected directly across the terminals of the generator. The current coil, or coarse wire winding, is in series with the circuit between the generator and the storage battery, and the circuit is opened and closed at the contacts A. When the engine is started, the generator voltage builds up and when it reaches about six volts a current passing through the voltage winding produces enough magnetism to overcome the tension of the spring B, attracting the magnet armature C to core D, which closes the contacts A. These contacts close the circuit between the generator and storage battery. The current flowing through the coarse wire winding increases the pull on the armature and gives a good contact of low resistance at the contact points.

Delco systems used during 1915 consist of single armature motor-dynamos, one application of which is shown in Fig. 280. The armature carries two commutators, one on each end or both on the front end, the rear end commutator being for the starting motor action.

Two separate field coils are used; a shunt for

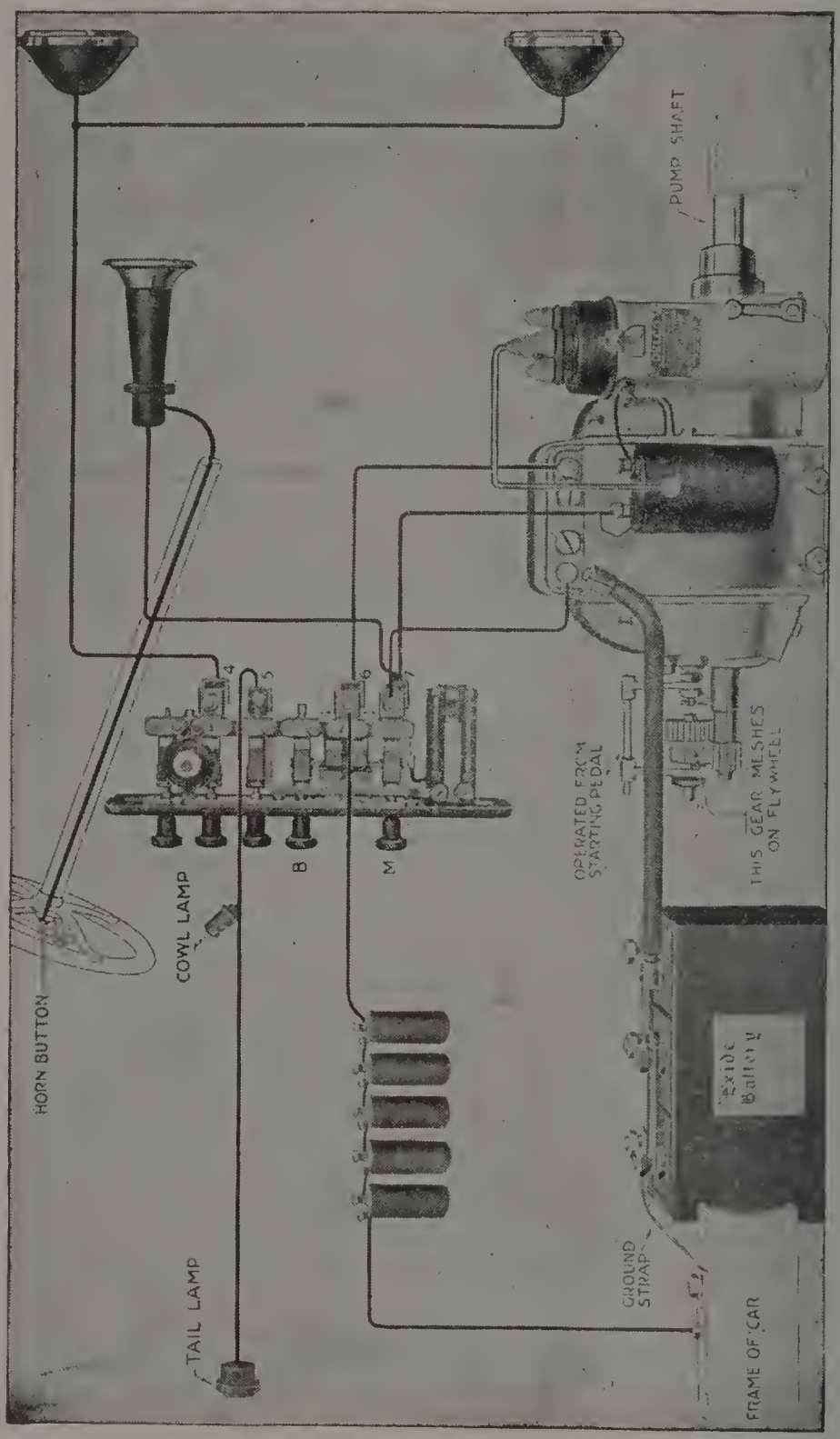


Fig. 280 Delco Starting and Lighting System, 1915 Type With Governor Control for Amperage

the dynamo action and a series for the starting motor action. These coils are both on the same field magnet core and have separate terminals.

The drive as a dynamo is from the rear extension of the pump shaft through a roller overrunning clutch which releases when the armature turns at high speed as a starting motor.

The starting motor drive is through a pinion on the rear end of the armature shaft to a ring gear on the flywheel. Two gears, fastened together, are free to rotate as a pair on an auxiliary shaft, the gears being slid along this shaft by a yoke connected to the starting pedal until one is in mesh with the armature shaft pinion and the other with the flywheel gear, completing the drive connection. A roller clutch is incorporated in the front one of the pair of sliding gears, this clutch releasing while the armature is being driven as a dynamo.

Starting switch action is secured by normally holding one of the motor commutator brushes away from the commutator by means of a rod connected to the starting lever or pedal. When the lever or pedal is moved this rod is drawn back so that the brush drops onto the commutator under the action of its spring, completing the circuit from the battery through the series winding and armature. This rod is fastened to the sliding gears so that they must be in mesh before the brush can drop.

The dynamo brush that is grounded completes its connection to ground through a pair

of contacts, one stationary and one movable, Fig. 281. The movable contact is attached to an arm on the movable starter brush in such a

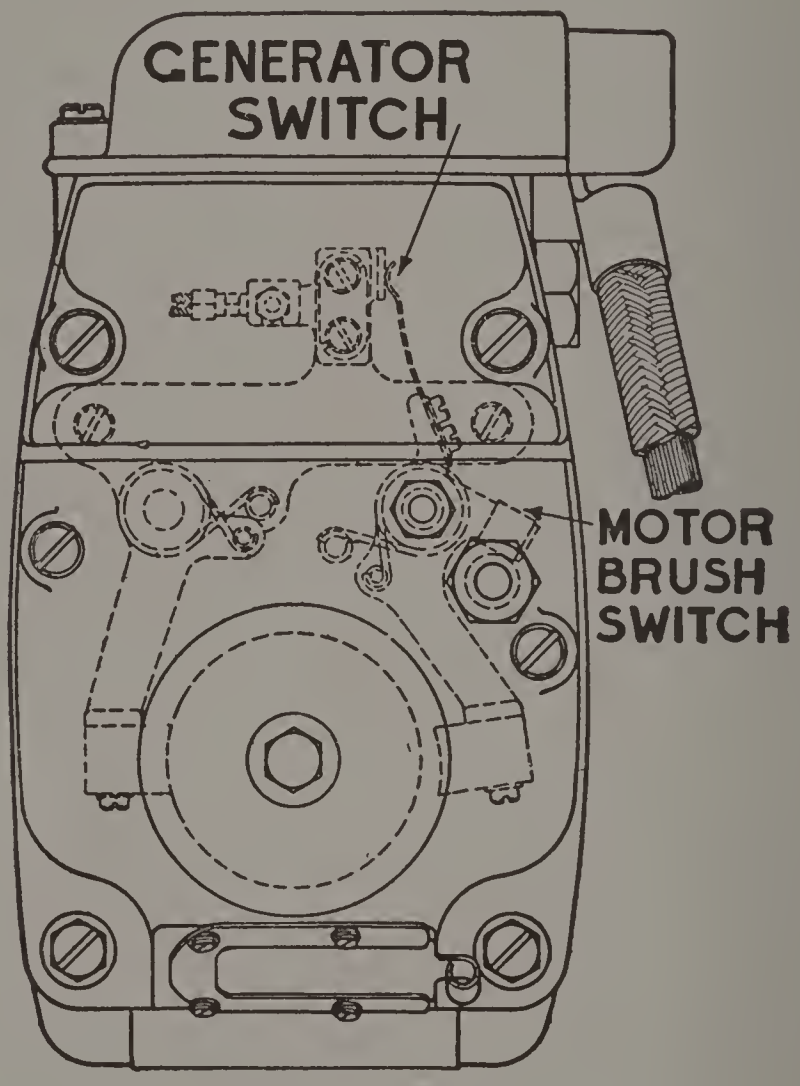


Fig. 281
Commutator End of Delco Governor Controlled Motor-Dynamo

way that the contacts open as the starter brush drops onto the commutator. This prevents dynamo action while the armature is acting to start the engine.

No fuses are used, but there is a magnetic circuit breaker, the electromagnet of which acts to open the contacts from the battery and dy-

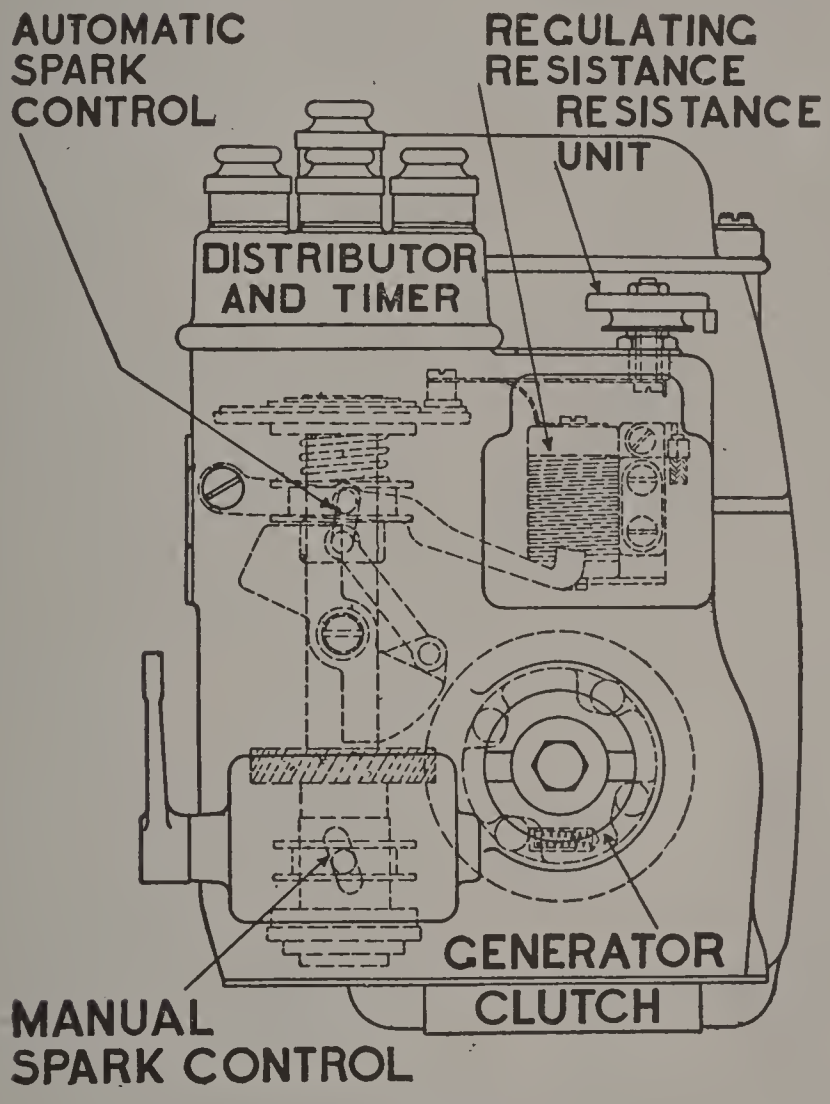


Fig. 282

Governor and Overrunning Clutch Mechanism of Delco Motor-Dynamo

namo to the lamp and car wiring when 25 amperes flow. After the circuit breaker opens the contacts continue to vibrate open and closed if

there is a flow amounting to five amperes. The circuit breaker will not stay closed until the ground or short circuit that is causing the leak of current has been removed. The spring of this current breaker should not be adjusted in any way as it is a safety device.

Delco systems may have any one of three different systems for regulating the dynamo output. One type consists of a differential or bucking coil carried on the field magnets and connected in series with the main line from the dynamo brush to the dash switch unit.

Another method makes use of a coil of resistance wire carried on a spool in the front end of the dynamo case on the right hand side, Fig. 282. One end of the shunt field winding is grounded through this resistance coil so that the field current would have to pass through the coil. This high resistance would allow but little flow and would weaken the field to such a point that the output would be very low. When the dynamo is running at low speeds the field current, after passing to the lower end of the resistance coil, goes to the ground through an arm making contact with the coil. This arm carries a contact which slides up and down on the resistance coil, the arm being moved by a centrifugal governor attached to the ignition distributer shaft. As the dynamo speed increases, the governor weights cause the movable arm to raise so that its contact is farther from the bottom of the resistance coil, and the field

current must consequently flow through a greater length of resistance wire before reaching the contact on the arm and passing to the ground. This greater resistance in the shunt field circuit allows less current to flow and by thus weakening the field cuts down the dynamo output at high speeds.

The third system of regulation also causes the shunt field current to pass to the ground through a coil of resistance wire. This resistance coil is wound on a spool and the spool is carried at one end of a rod, the other end of the rod forming the plunger of a solenoid coil. The strength of this solenoid increases with the voltage, being connected in shunt with the brushes. Increased strength of the solenoid pulls the plunger farther into the coil. This solenoid coil is in the upper end of a cylindrical housing, and the resistance coil is carried below the solenoid. The plunger and resistance are normally in a low position but are raised by the solenoid action. In the low position the resistance coil dips into a well partly full of mercury so that the shunt field current does not have to pass through all the resistance wire but passes into the mercury and to the ground from a contact fastened to the mercury well. As the voltage rises the solenoid becomes stronger, lifting the plunger and pulling the resistance coil up out of the mercury well so that the shunt field current must flow through a greater length of resistance wire before reaching the ground. This

added resistance allows less current to flow through the shunt field and consequently lowers the field strength and the output of the dynamo.

Delco systems use either of two methods of reverse current cut-out. One type comprises a dash switch with five buttons. The three left-hand buttons are for the lights, the two right-hand being for the ignition. The button on the extreme right is for the storage battery ignition, the one next to it being for the dry cells. Each of these buttons carries two contacts inside the switch, one completing the ignition circuit and the other completing the charging circuit. When the engine is to be started either of the ignition switches is pulled out. The current then passes from the battery to contact (1) on the switch, through the inner connection of either dry cell (Bat.) or storage battery (Mag.) switch and out of terminal (6) to the shunt dynamo winding and armature brushes. This causes the dynamo parts to act as a motor of very low power and the armature revolves slowly so that the starting gears can be meshed. As soon as the gears are meshed the motor brush drops onto its commutator and completes the starting circuit while breaking the dynamo circuit as described before. The battery current will then cease to flow through terminal (6) but will flow through the circuit breaker, whose points are held closed by a spring, and through the other connection on the switch button plunger, out through terminal (7) and to

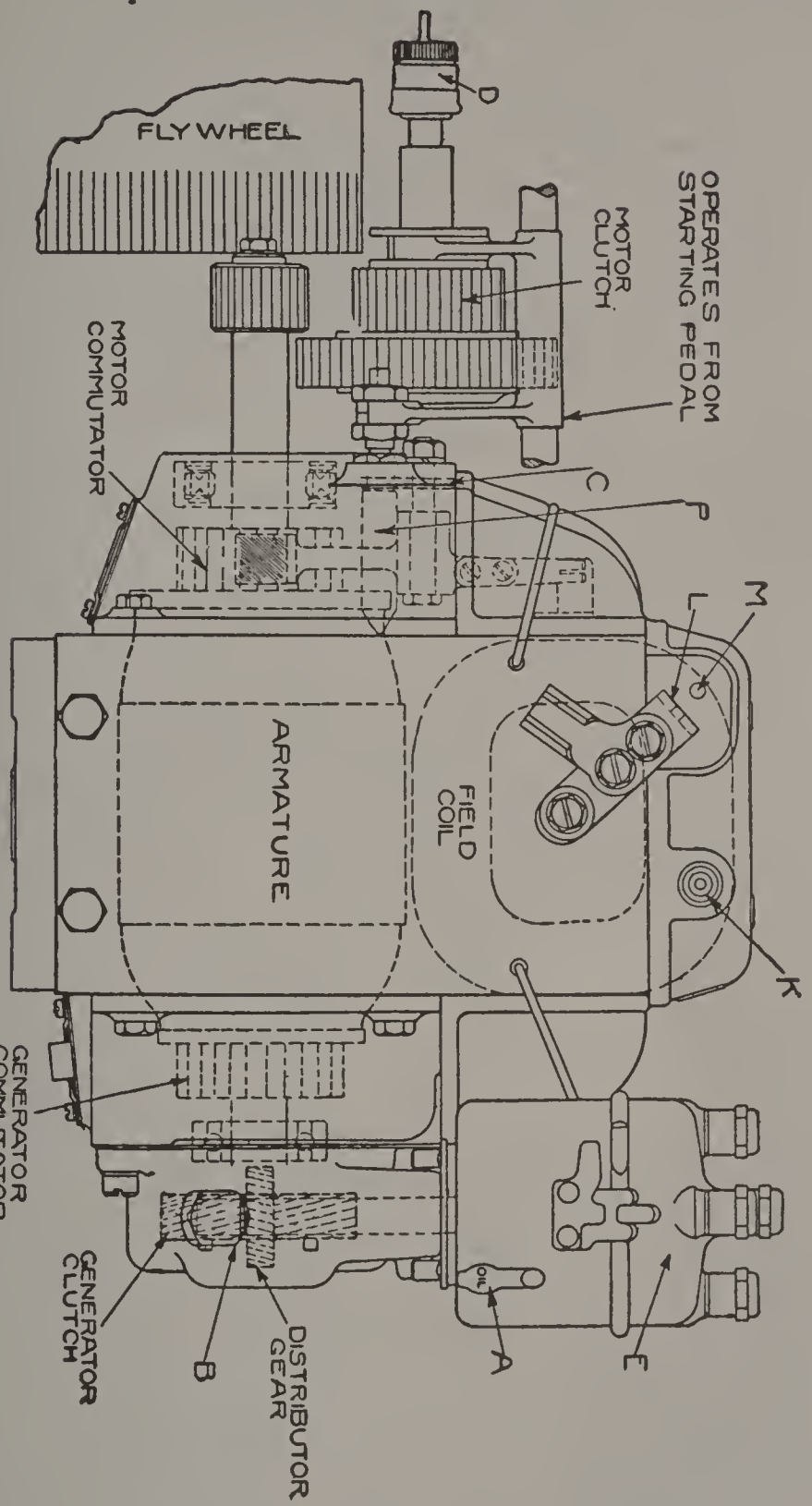


Fig. 283
Delco 1916 Motor-Dynamo With Third Brush Control

the ignition coil. If the "Bat" button is pulled out the dry cell current comes into terminal (2) and out through (7) to the ignition coil. When the engine has been started and the dynamo generates a voltage greater than the battery, current will flow from the dynamo through the differential winding (if one is used) into terminal (6), through the inner contacts of the switch and out through (1) to the battery. If the ignition switches are left closed with the engine idle the battery will discharge through the switch contacts and dynamo parts, these switches acting as the cut-out with the dynamo and engine idle.

The construction of Delco apparatus used during 1916 differs from that already described in one important particular. The output of the dynamo when charging the battery is controlled by the "third brush" principle.

One of the applications is shown in Fig. 283 and it will be noted that the armature and field location, starting drive and ignition mechanism is similar to the forms previously used. The brush position is shown in Fig. 284. The action is explained as follows: The full voltage is obtained between the large brushes and the voltage between the left hand large brush and the small regulating brush is less than the full pressure. This reduced voltage is applied to the field coils. With the armature rotating, the magnetic field is twisted out of its normal path between the pole pieces, the degree of deflection

being in direct ratio to the increase of speed. This deflection causes the magnetic flow to be-

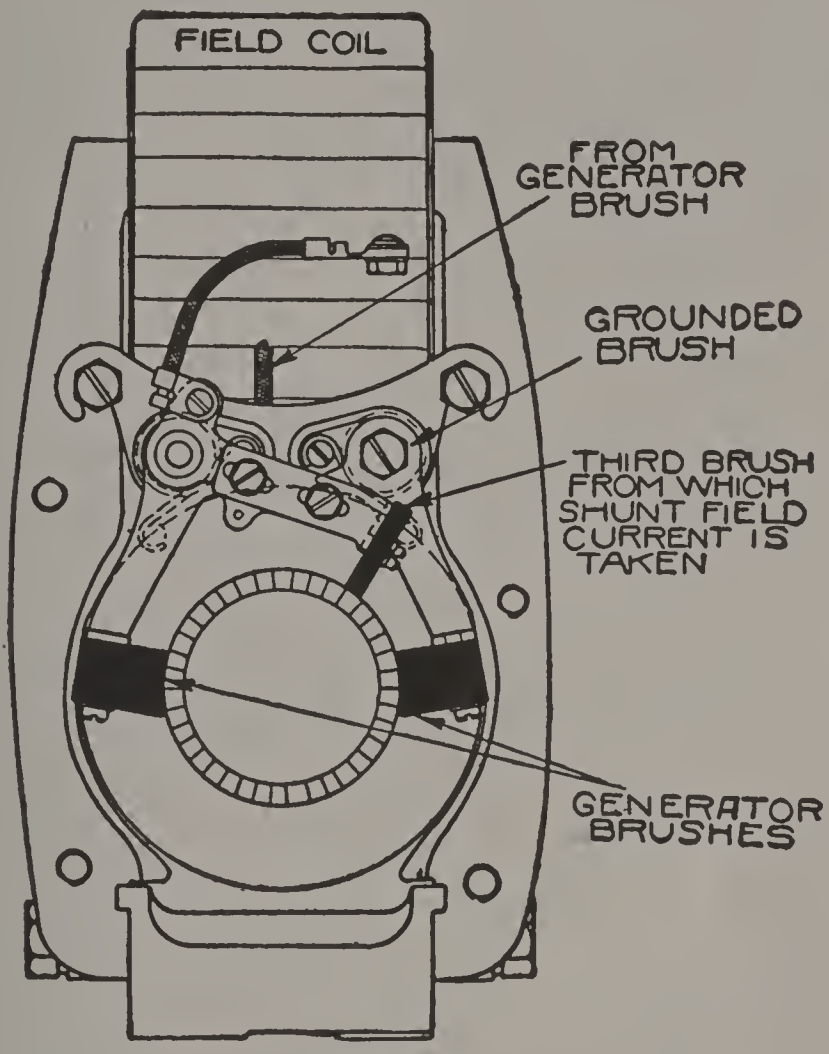


Fig. 284
Brush Mechanism of Delco Motor-Dynamo

come weaker at the points on the pole pieces that affect the flow into the "third brush" and this weakened field current compensates for the higher output that would otherwise be caused by increase of speed. Fig. 285 shows the starting motor end of this same machine.

Another application of the third brush dynamo does not make use of the motor-dynamo

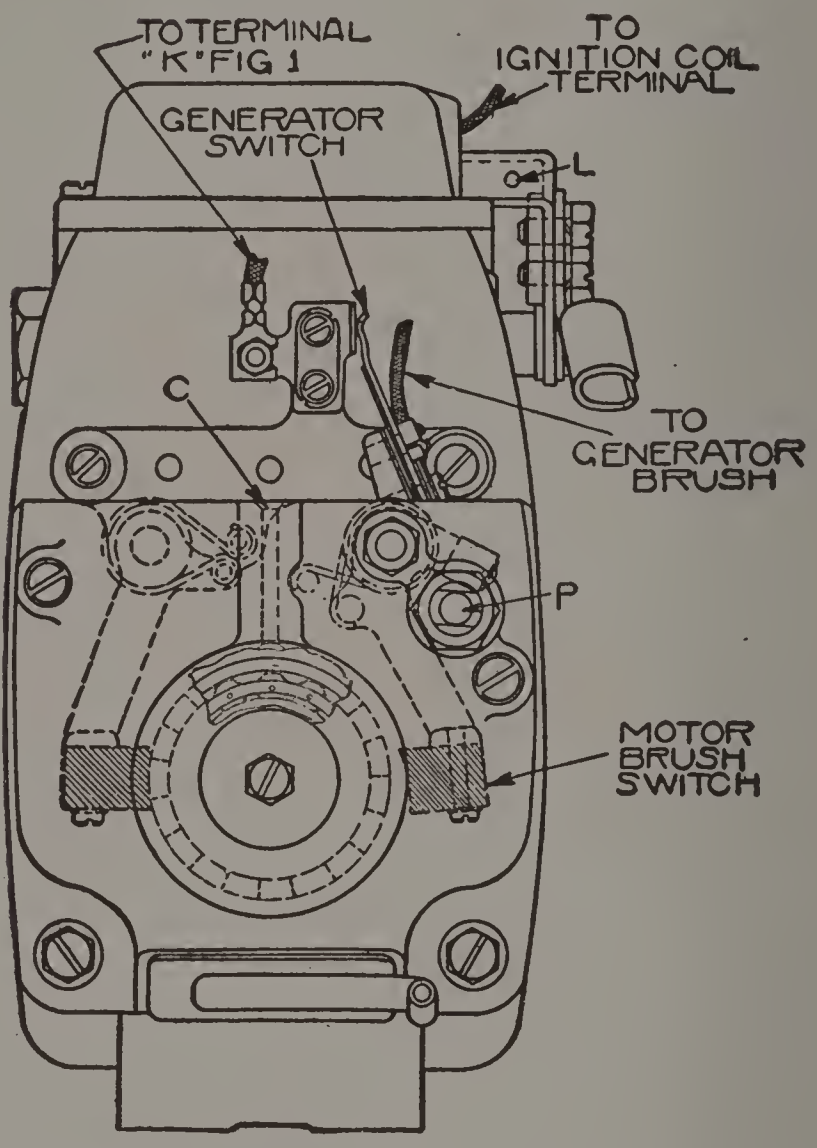


Fig. 285
Motor Brush Switch Connections of Delco Motor-Dynamo

combination, but uses a separate series wound motor driving to the flywheel through a Bendix screw.

Dyneto and Entz Equipment. These installations make use of a combined motor-dynamo operating with twelve volts in some cases and with eighteen in others. A compound field winding is used, series and shunt coils acting

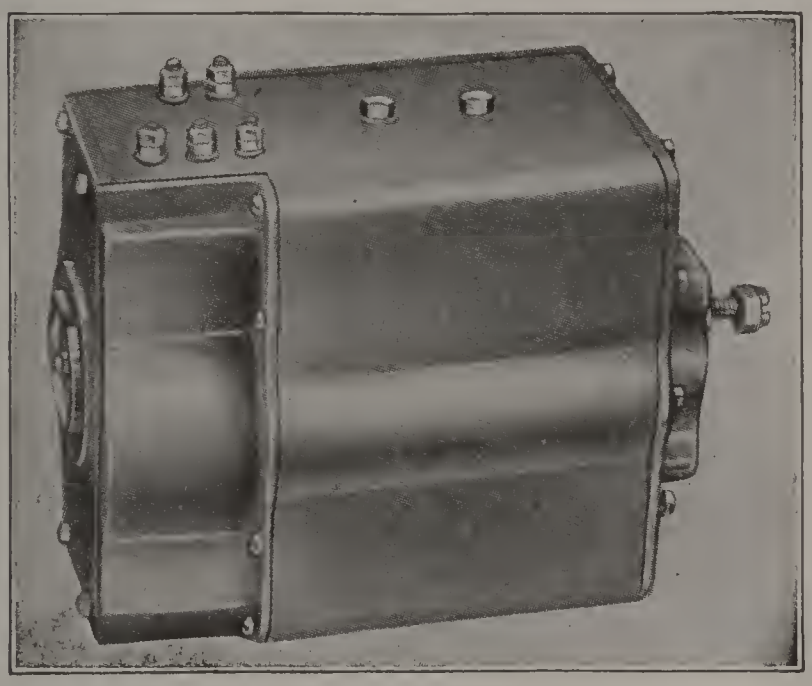


Fig. 286
Five Terminal Dyneto-Entz Motor-Dynamo

together in starting and forming a reversed series controlled machine in generating. The reversal of the direction of flow through the series field while generating causes this winding to oppose the shunt winding at high armature speeds and the dynamo output is thereby limited to a safe maximum.

Dyneto and Entz outfits do not make use of a cut-out of the usual form. The motor-dynamo is placed in circuit with the battery when the starting switch is closed and this switch is left closed as long as the machine operates. As soon as the unit has started the engine, the

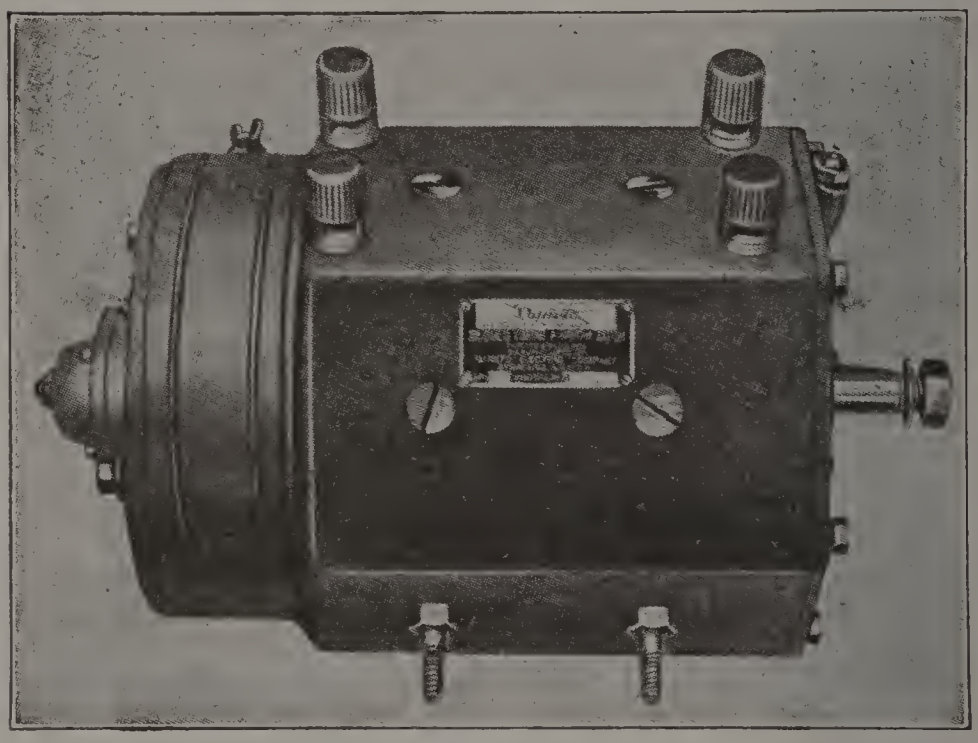


Fig. 287
Four Terminal Dyneto Motor-Dynamo

engine causes the armature speed to increase to a point at which the voltage is greater than the battery and charging then commences. If, at any time, the armature speed falls below a certain point the machine again resumes its action as a starting motor.

The ignition is controlled by the same switch that makes the battery and motor-dynamo circuit. With this switch in the "Off" position, the ignition is inoperative and the battery is disconnected from the motor-dynamo. With the switch in the "On" or "Running" position, the ignition is on and the battery is connected to the electric machine. A switch position midway between the two mentioned is provided, this position being called "Neutral." With the switch at "Neutral," the ignition is operative but the motor-dynamo circuit is open so that the battery will not discharge, and the machine will not act as a starting motor at low engine speeds.

The number of terminals differs on various types; one with five connections being shown in Fig. 286 and another unit with four terminals being illustrated in Fig. 287.

Gray & Davis Equipment. The type of equipment used from 1912 to 1914 is described below.

This system comprises two units: 1, the starting motor; 2, the dynamo for charging

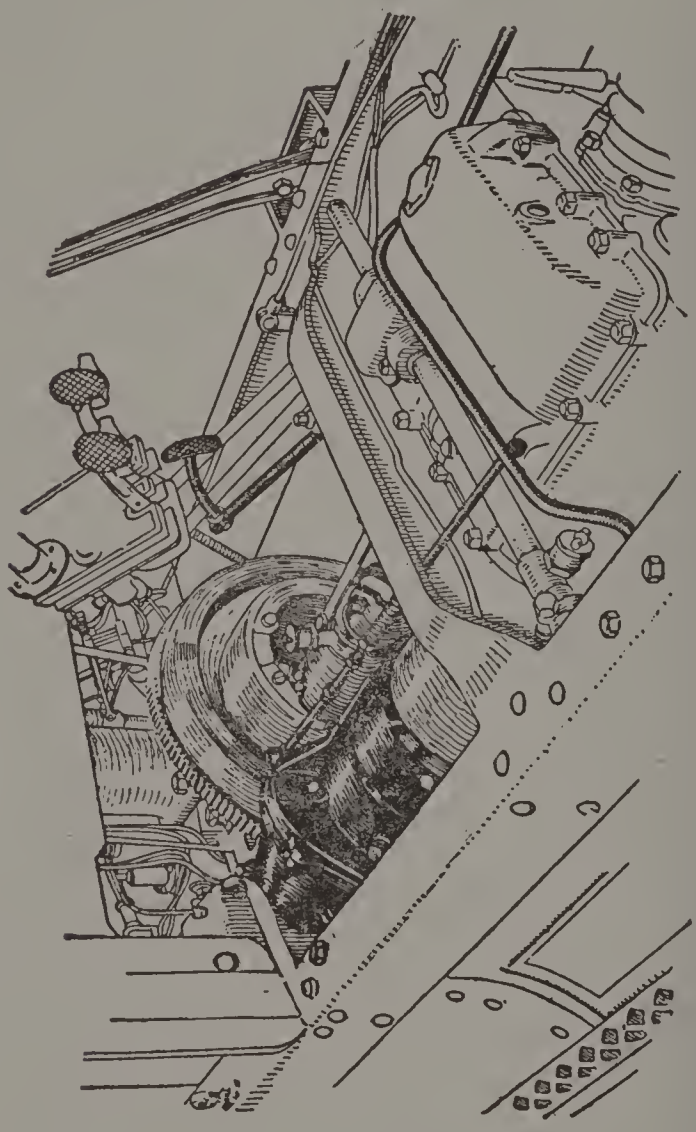


Fig. 288—Gray & Davis Electric Starter on Car.

battery and lighting. The function of the dynamo is to furnish current for lamps and current for the battery. The starting motor starts the engine. This motor is connected with the flywheel by gears, and when a starting pedal is

pressed the motor turns the flywheel and crankshaft and keeps turning until the engine "picks up." The starting motor then automatically ceases to operate.

The dynamo system includes the following: 1, a constant-speed dynamo, driven from the engine or jackshaft by gear or a silent chain; 2, a governor, to take care of the varying speed of the engine; 3, an electric cut-out, to disconnect the dynamo from the battery when running below the charging speed; 4, a battery to operate the lights when the dynamo is not running at the necessary speed or when the engine is stopped. This battery may also be used for firing the engine.

1. The dynamo is of the compound-wound type, designed to run at a constant speed of 1000 revolutions per minute. The system is so wired that the series field is carrying current only when the lights are burning. See Fig. 289.

2. The governor is of the simple, centrifugal type, but operates a friction clutch of new design. In operation the clutch slips just enough to hold the dynamo speed always at 1000 r. p. m., whether the engine speed corresponds to a car speed of 13 or of 60 miles an hour.

3. The electric cut-out consists of an electro-magnet with a compound winding, the fine wire part of which is connected across the dynamo terminals. Its function is, as stated, to disconnect the dynamo from the battery when the engine is running very slowly or is at rest.

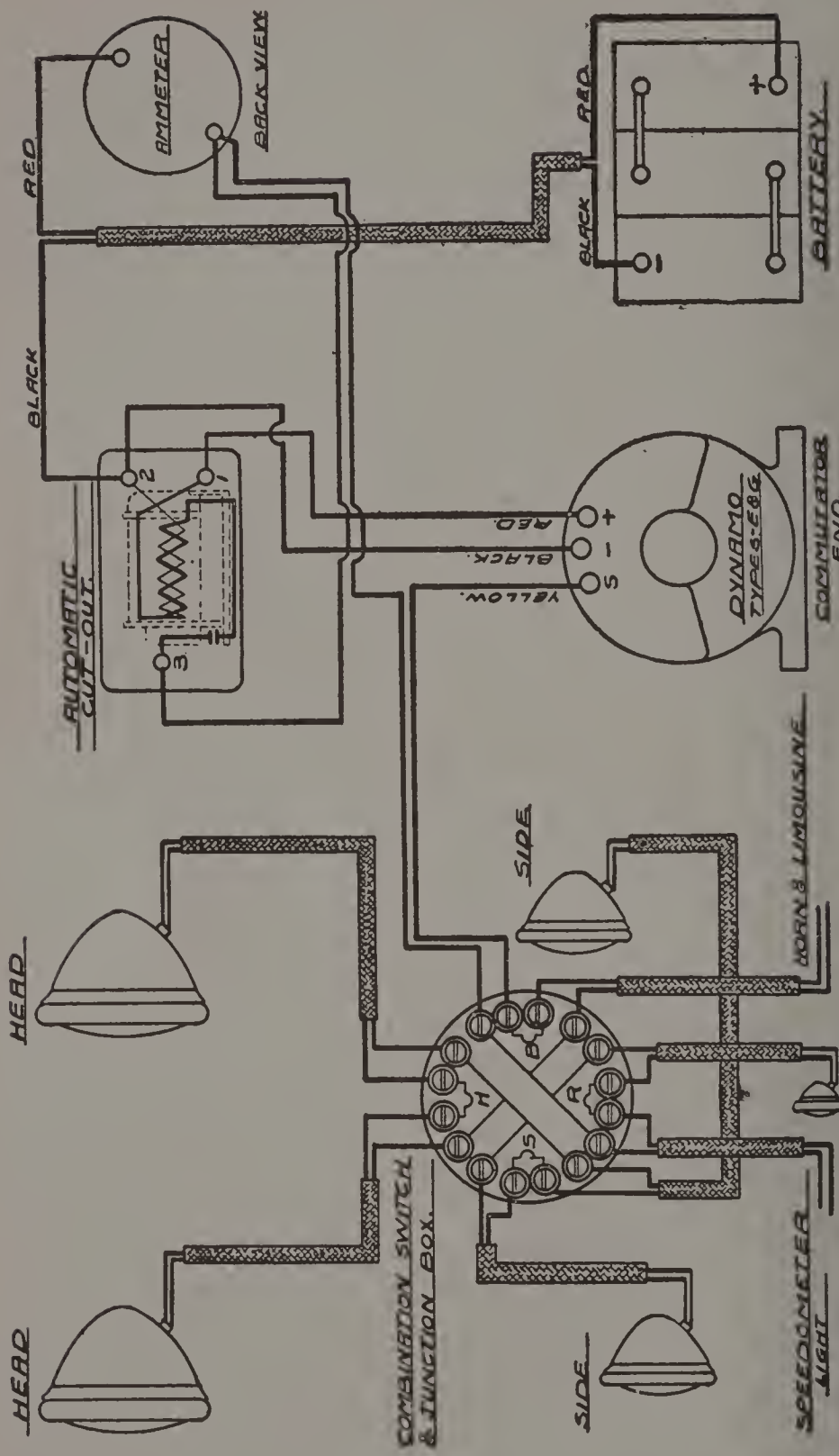


Fig. 289—Wiring Diagram G. & D. Dynamo System.

If an automatic switch of this nature were not in the circuit the battery would discharge through the dynamo when the dynamo was no longer maintaining charging voltage.

4. A battery rated at 6 volts, 80-ampere

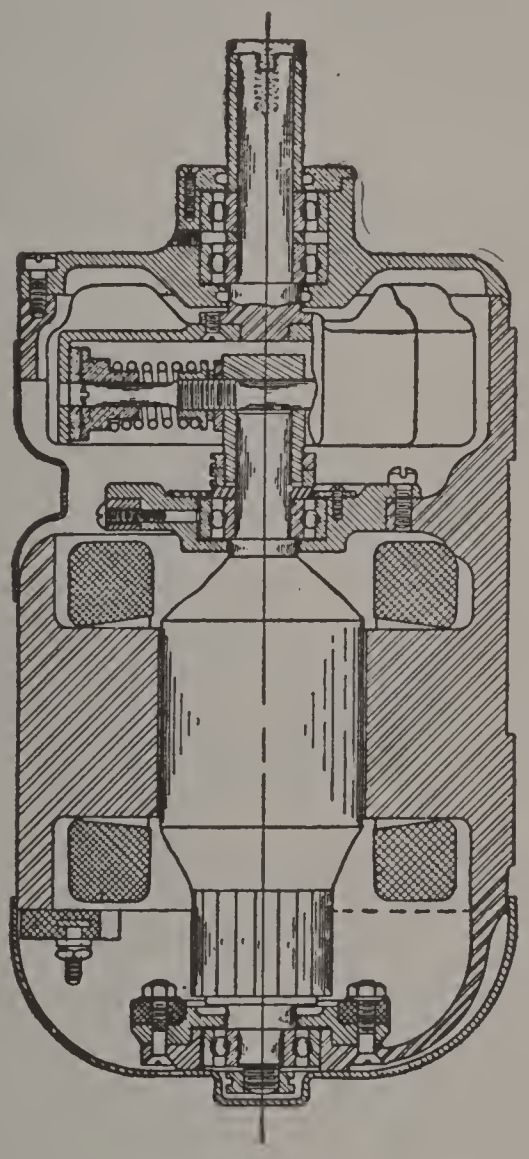


Fig. 290—G. & D. Type "G" Dynamo. Outline Showing Dynamo and Governor Mechanism.

hour capacity at a discharge rate of 8 amperes is furnished with this system sufficient to carry the full lamp load for ten hours or the side and tail lamps for thirty hours. The arrangement

of the switch connections is such that the dynamo operates as a shunt-wound machine while charging the battery and as compound-wound when supplying the lamps directly. This gives the battery a tapering charge.

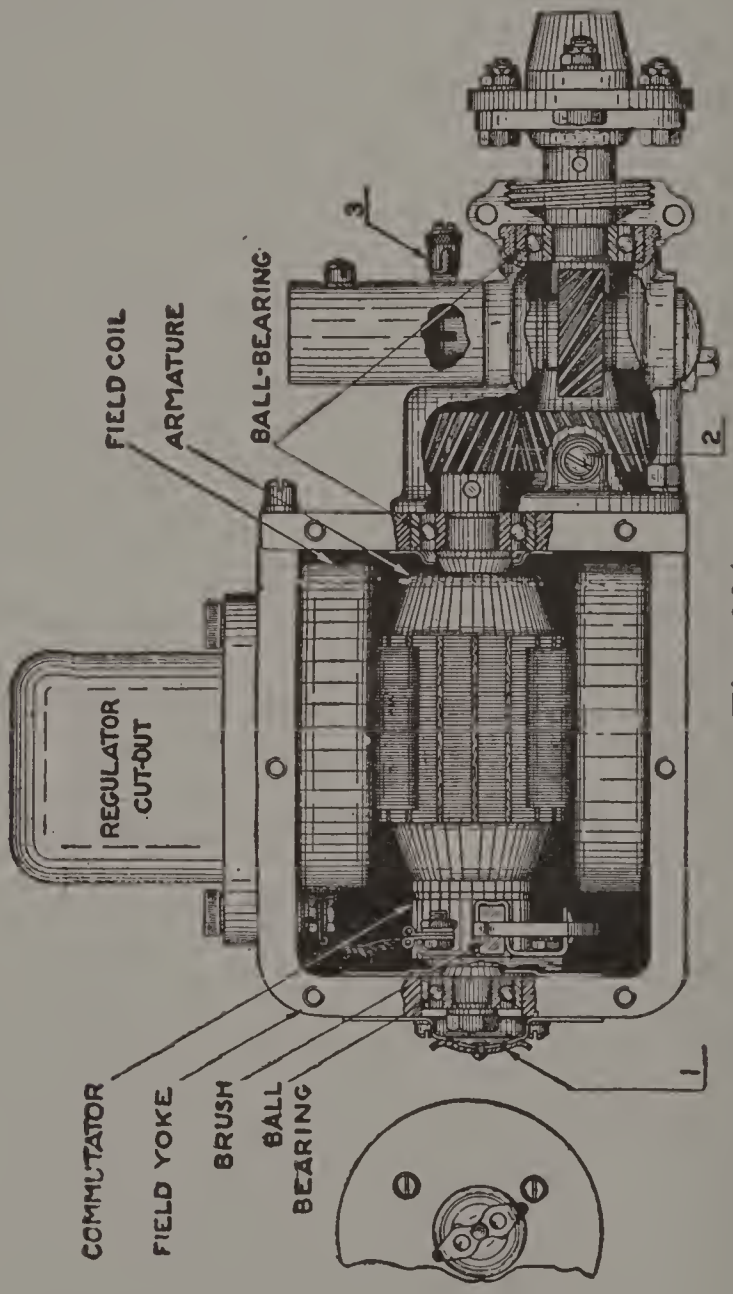


Fig. 291
Gray & Davis Dynamo With Vibrating Regulator
1, 2 and 3, Oil Holes

The wiring for this system is plainly shown in the accompanying diagram. See Fig. 289.

The newer models of Gray & Davis equipment make use of a separate dynamo or ignition-dynamo with a combined output regulator and cut-out carried in a housing on top of the unit.

The interior construction of the dynamo is shown in Fig. 291, the particular model illustrated being arranged for carrying an ignition head at the drive end and providing a spiral gear drive.

The cut-out and regulator are in the same case and the one large electromagnet operates both. This magnet carries two windings, shunt and series. When the dynamo is idle the cut-out contacts are open and the two regulator contacts are closed, being held that way by their respective springs. Fig. 292. Current enters the shunt coil of the controller through the grounded end and down through the terminal A to the negative brush, thus receiving current from between the brushes whenever the dynamo runs. When the voltage rises to a point in this coil so that the magnet overcomes the tension of the cut-out spring the cut-out contacts close. Current which has passed from the grounded positive brush of the dynamo through the battery in charging, returns to the terminal B and passes through the entire length of the series coil on the magnet before going through the cut-out contacts to the terminal A and negative brush. Current which has passed through the lamps returns to the terminal L and through only a part of the series coil on the magnet

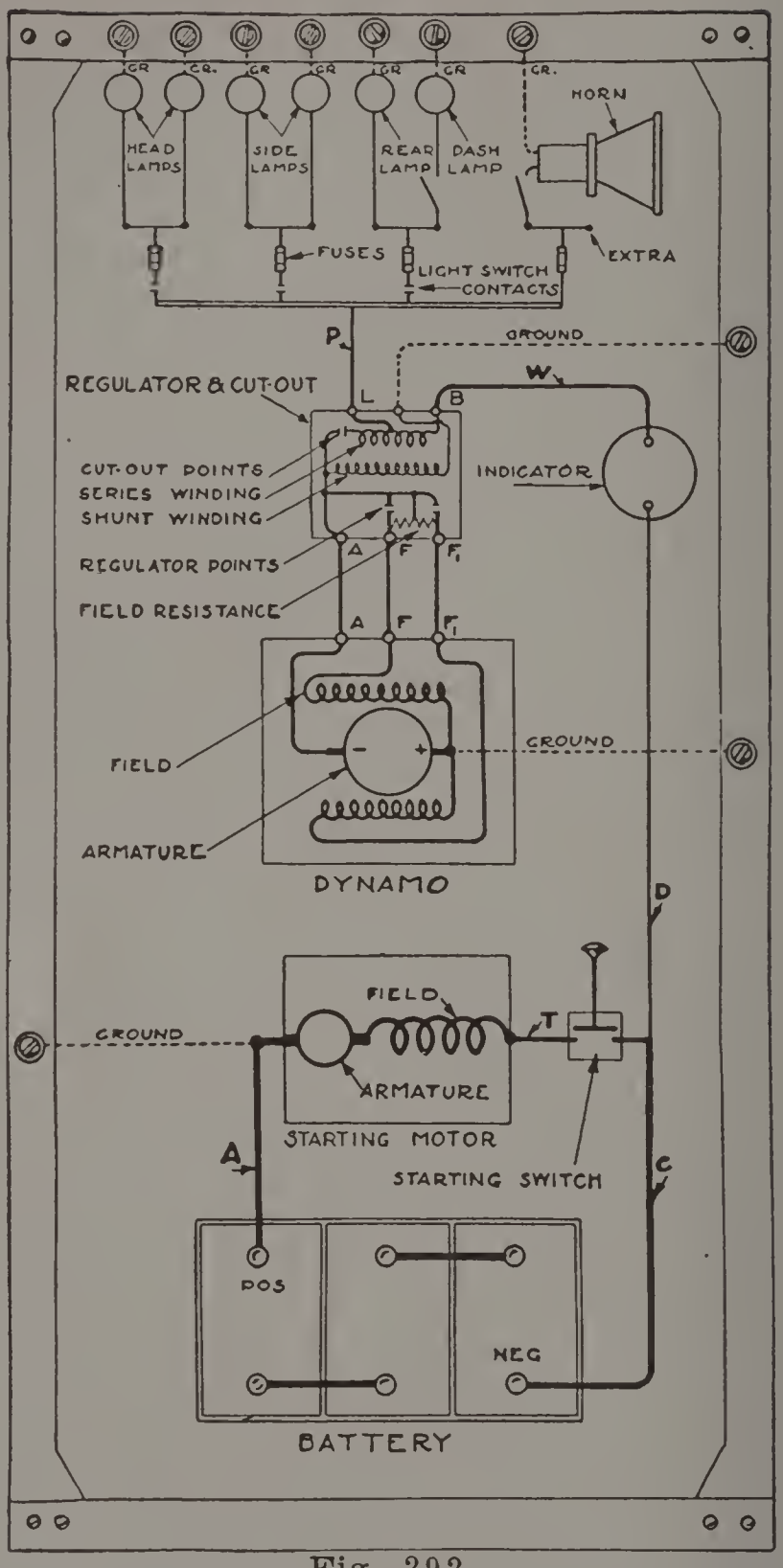


Fig. 292
Internal Connections of Gray & Davis Vibrating Regulator System

before reaching the negative side. The more lamps are turned on the more current they take and the less current is left to pass through the battery. It will therefore be seen that if enough lamps were turned on to leave nothing going through the battery the part of the series coil between L and B would carry no current and the strength of the magnet would be weakened. For the same reason it will be seen that the more lamps turned on the weaker this coil and magnet become. This is part of the regulator action as will be explained.

The regulator action is as follows: Current passes from the positive brush through the shunt field and into the terminals F and F1, then through the regulator contacts which are closed and back to the terminal A to the negative brush. As the voltage passing through the shunt magnet coil increases after the cut-out has closed, its strength finally reaches a point where the tension of the regulator contact spring is overcome and the contacts are pulled open. The current from terminals F and F1 must now return to the negative brush through the resistance wire coils seen between the two regulator contacts, this resistance retarding the flow and weakening the dynamo fields and consequently lowering the output and voltage until the weakened magnet allows the regulator contacts to again close. This action causes these contacts to vibrate and keep a steady output. As explained above, the strength of the magnet

is decreased as more lamps are turned on, so that the regulator contacts remain closed for a longer time, and, as the resistance is not in the field when they are closed, the output is allowed to rise to care for the added lamp load.

The cut-out is of the simple electromagnetic type. The action of the regulator allows the battery to receive a small charge even with all lamps on.

Removable plates cover either side of the dynamo, allowing access to the inside without disturbing any parts or wires.

A charge indicator is located on the dash or cowl. The pointer turns upward if current is passing to the battery and downward when current passes out of the battery for any purpose. If the pointer is straight across the battery is neither charging or discharging. This indicator should show charge at car speeds above 10 to 12 miles per hour.

The output of the dynamo may be tested by turning on all lamps and disconnecting the wire from terminal B. The lamps are then burning directly from the dynamo and if they go out the dynamo is at fault.

The regulator and cut-out may be tested by connecting a wire from terminal A to terminal B while the engine runs at a speed which would correspond to a car speed greater than 10 miles per hour. If the indicator then shows charge when it failed to show this before the test the cut-out or regulator is at fault. If the indi-

cator remains straight across something is preventing the dynamo from delivering its current.

The lighting switch is of the rotary snap type and carries all lamp and circuit wires on the engine side. On the back of the switch are four fuses in clips. Near the fuses are letters H, S, R and B, indicating the fuses for head, side or dimmer, rear and tail, ignition and horn circuits respectively.

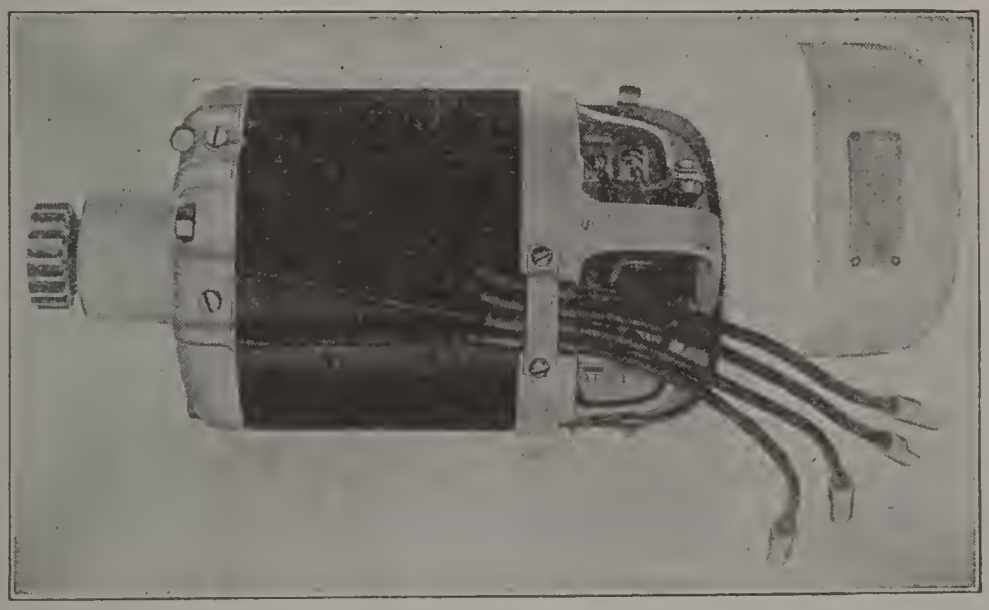


Fig. 293
North East Motor-Dynamo

The starting motor drives into a flywheel ring gear or crankshaft through sliding reduction gearing and overrunning clutch. The starting switch pull rod operates the sliding gear through

a coil spring so that switch contacts may close whether gears are in position to mesh or not, the first turning of the armature causing the gears to snap into mesh under the action of the compressed spring. One side of the starting switch may be grounded or the lead from the positive motor brush may be grounded. In either case two wires lead to switch and starting motor.

North East Equipment. This starting and lighting system makes use of a combined motor-dynamo having two field windings, a shunt and series. The series field is used for starting and the two fields compound for generating. One of these units is shown in Fig. 293.

The brushes and commutator may be exposed by removing a cover from the end opposite the drive. The upper part of this cover, which encloses the brushes, is held in place by spring clips, but the lower half is fastened with bolts that are sealed at the factory. This lower half encloses a combined cut-out and regulator. The cut-out is of the electromagnetic type and serves to connect the dynamo with the battery when the generating voltage is sufficiently high to make charging possible, also to disconnect the battery when the dynamo voltage falls below that of the battery.

The regulator is of the vibrating reed type, having two sets of contacts operated from one electromagnet. The current output of the dynamo passes through the winding of the regu-

lator electromagnet and causes the contact to open when the amperage has reached a certain predetermined limit. With the contacts open, the field current, which has previously passed through the contacts, must flow through two spools of resistance wire. The consequent reduction in field current prevents further rise in output.

North East equipment is of the two voltage type, the starting voltage being either 12, 16 or 24, while lighting and charging is accomplished at 6, 8 or 12 volts. Starting and charging circuits are of the two wire type, while lighting circuits may be either one wire with ground return or two wire throughout. A field fuse is carried in the brush and commutator compartment of the motor-dynamo, this fuse blowing out should the battery or charging lines become disconnected while the motor-dynamo is operating.

The unit is driven from the engine and drives to the engine through a silent chain, with or without spur gear reduction.

Remy Equipment. Remy apparatus consists of a variety of types, each one suited to the particular requirements of the cars to which it is applied. A complete internal circuit diagram of one of the separate unit systems with separately mounted regulator and cut-out is shown in Fig. 295.

Remy equipment may be made up of all separate units for lighting, starting and igni-

tion, with or without Remy magneto or battery ignition. The separate unit systems all make use of a shunt wound dynamo of 6 volt output. The separate motors, Fig. 294, are of four pole, series wound type and operate on 6 volts.

A separate dynamo may be driven from a shaft to the timing gear case and have one of the separate motors mounted above it, forming

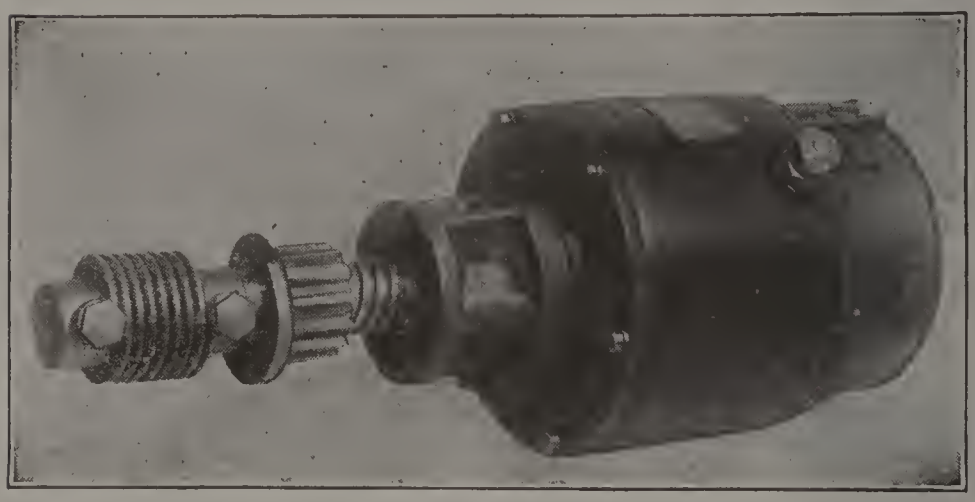


Fig. 294
Remy Starting Motor With Bendix Drive

a "double deck" instrument. The dynamo would be two pole shunt wound and the motor four pole series wound, both 6 volts. The motor drives down to the main shaft through two pair of spur reduction gears, the large gear on the main drive shaft carrying an overrunning clutch which runs free while the starting motor operates.

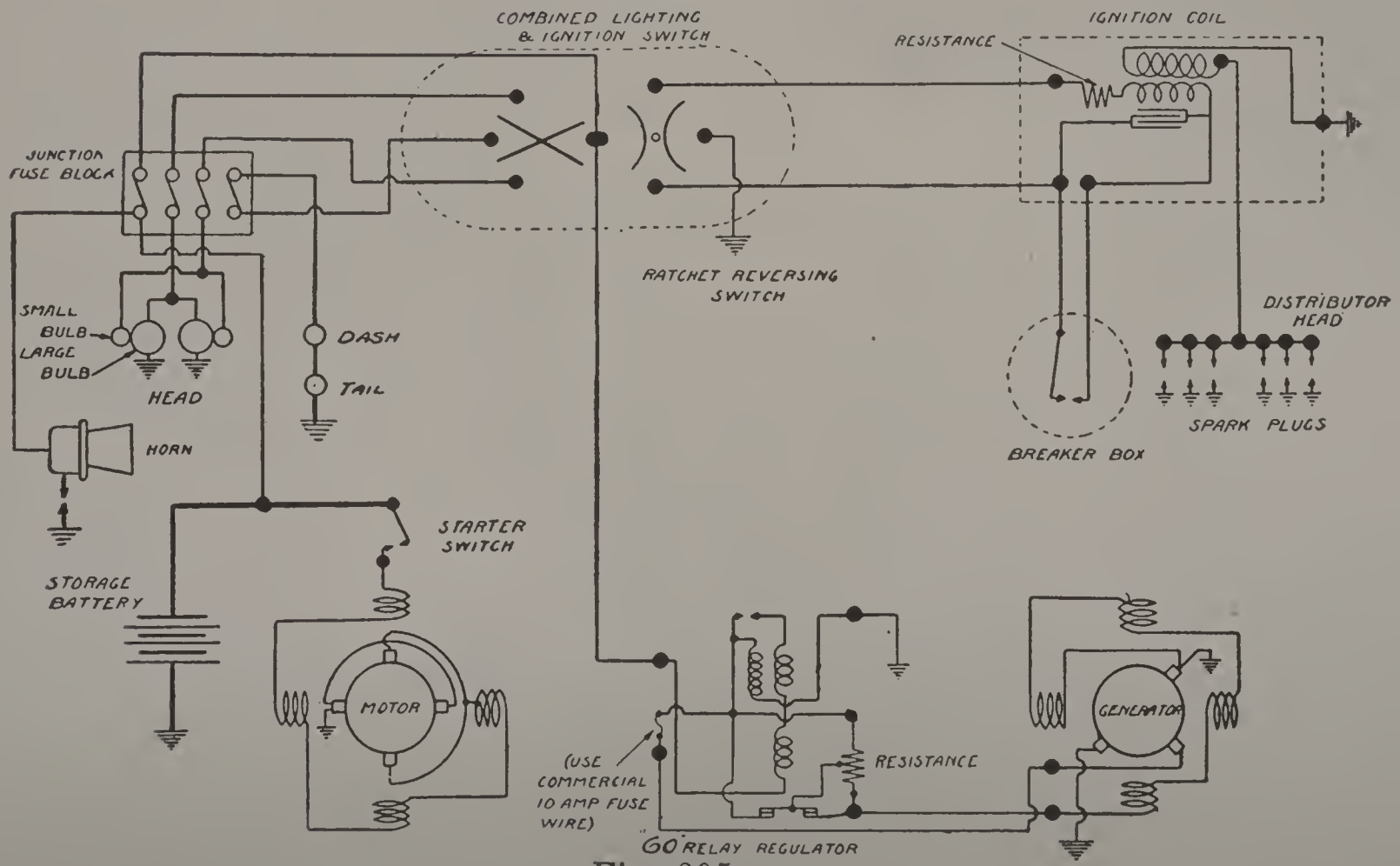


Fig. 295

Internal Connections of Remy System With Vibrating Regulator

Another Remy system makes use of a motor dynamo with only one armature. This machine is of the four pole type, compound wound and operates with 12 volts. No overrunning clutch or device taking its place is used with the single armature motor dynamos, these being direct connected in all cases.

Remy dynamos are also built with a magneto type breaker mounted on one end of the armature shaft with a magneto distributer carried above it, thus forming a combined dynamo-ignition outfit. The dynamos in this case are of the two pole shunt wound type operating with 6 volts. These machines are positively driven at engine speed in four cylinder cars one and one-half times engine speed in six cylinder cars and twice engine speed in eights. A separate 6 volt starting motor is used in connection.

The 12 volt motor-generators (as described) are also built with the ignition breaker and distributer added, forming a single unit having the functions of starting motor, dynamo and igniter in one.

Wiring for lighting, charging and starting circuits may be either two wire or one wire with grounded return. Switches, current indicators, junction boxes and dimmer resistance units vary with the make of car.

Regulation of the amperage is accomplished in either of two ways. One method is by the third brush being below one of the main brushes

on the left side facing the commutator. This brush takes current to one end of the shunt field winding, the amount of current flowing through this brush becoming less and less as the speed increases. The position of the brush is not adjustable.

The other method of regulation consists of an electromagnet carried in the same case with the cut-out and operating to insert a coil of resistance wire, also carried in this case, into the shunt field circuit as the amperage rises.

The cut-out is of the electromagnetic type with two windings, shunt and series. The circuit should close in the neighborhood of ten miles per hour, preferably at lower speeds. The cut-out mechanism or combination of cut-out and regulator may be mounted on the dynamo housing at the drive end over the armature shaft or as a separate unit on the dash or other convenient location.

The current output should be about 7 amperes at 8½ to 12 miles per hour, rising to a maximum of 10 to 14 amperes, depending on the installation.

Starting motor drive may be through reduction gearing inside the housing as described for the double deck instruments; or by chain with overrunning clutch on separate motors but without the clutch on motor-dynamos. Separate motors also use the Bendix type of inertia pinion drive.

Starting switches are of two types, both making the circuit complete without preliminary contacts. One uses the conventional type of tapered plunger, the other uses copper bands sliding on two cylinders, the cylinders being made of insulating material and carrying contact bands in such a position that the sliding rings complete the circuit from one cylinder to the other when fully depressed into position. Either switch may act by push or pull rods or foot buttons.

Fuses for each of the lighting lines are carried in the lighting switch. A 20 or 25 ampere fuse in circuit with the dynamo field is mounted above the magnet in separate cut-outs or on the base of combined regulators and cut-outs.

Rushmore Equipment. The Rushmore system was originally manufactured by the Rushmore Dynamo Works, but this company is now a part of the Bosch Magneto Company, and the product is known as "Bosch-Rushmore" and "Bosch." The several unique features found in this equipment are described on the following pages:

THE RUSHMORE ENGINE STARTER. The Rushmore electric starting motor, shown in Fig. 296, acts directly on the flywheel without intermediate gears, a pinion keyed fast on the motor shaft meshing with a gear on the flywheel rim. This pinion is normally out of engagement. The closing of the starting switch causes the pinion automatically to engage the flywheel gear before the armature starts rotating. As soon as the engine picks up, the pinion automatically slides out of mesh, and remains out no matter how long the starting switch is held closed. There is no mechanism except the starting motor itself and the starting switch.

When the starter is not in use the armature is held normally out of line endwise with the pole pieces by means of a compression spring contained in and acting against the hollow armature shaft. Magnetic pull is employed to engage the pinion. The foot button starting switch has three contacts. At the first pressure upon the button the armature is drawn into the field with great force while rotating slowly so that the pinion teeth will engage. After the gears are fully engaged the third

contact applies the full force of the battery to turn over the engine.

The motor is series wound and produces a strong torque on starting. As soon as the en-

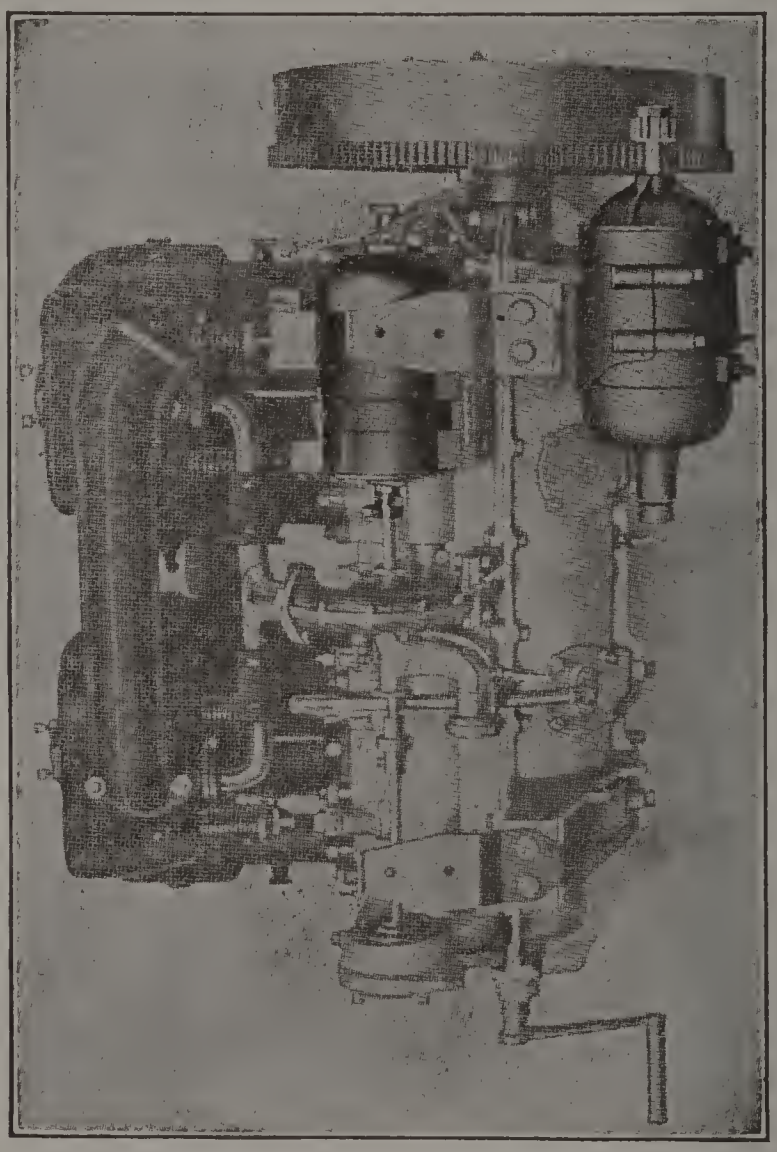


Fig. 296—Rushmore Dynamo and Starter on Simplex Engine.

gine picks up, the accelerated speed causes the counter electro-motive force in the motor to reduce the current flow to a value too small to hold the armature in line with the pole pieces against the end pressure of the spring. The

pinion then slips out of mesh and remains out, even with the circuit closed, because the current required to run the motor free is too small to overcome the spring. The armature will not again move endwise into its working position until it has stopped and the switch is again closed. The turning force developed at the flywheel rim is rated at over 400 lbs., suffi-

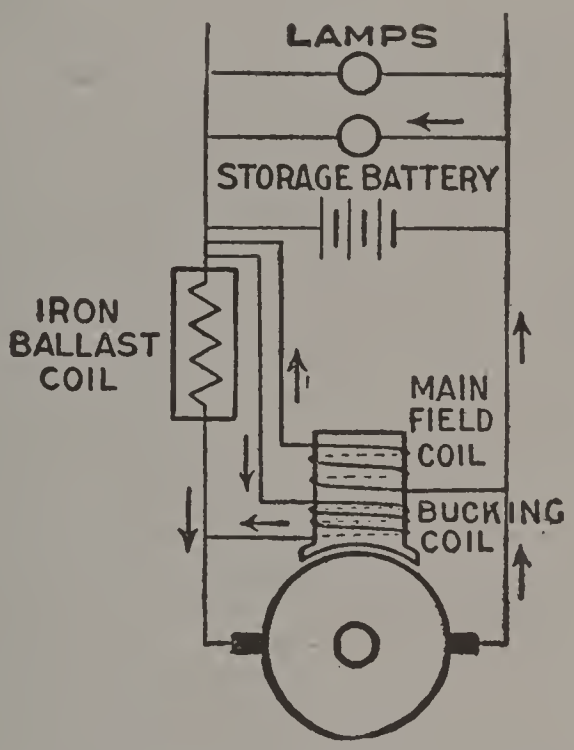


Fig. 297—Diagram of Rushmore Lighting System.

cient to start the largest engine with ease. The motor is wound for a 6-volt battery.

RUSHMORE LIGHTING SYSTEM. Essential elements of this system are: 1, the dynamo; 2, storage battery, 6-volt, of 80 to 160 ampere hours capacity, depending upon size of the headlights; 3, switch and terminal block on

dashboard, which simultaneously switches the headlights on or off and switches the ballast coil in or out of circuit; 4, wiring and circuit switches for small lamps.

Briefly the action of the dynamo is to reduce the strength of the field magnet at high speeds by means of counter excitation produced by a few turns of magnet wire, called a "bucking coil," on the field poles. The amount of current passing through this bucking coil is determined automatically by the varying resistance of a small coil of iron wire, called the "ballast coil," which is made in the form of a cartridge fuse and carried in clips on the switchblock in the main line between the dynamo and the battery. See Fig. 297. The effect of controlling the bucking coil by the current output is to produce an approximately constant current at the higher speeds.

Simms-Huff Equipment. This apparatus as generally mounted consists of a combined dynamo and motor with separate magneto ignition. One wire system with a grounded return for all circuits is used.

The motor dynamo is of the six pole type and has a differential compound winding. It generates 6 volts as a dynamo and operates with 12 volts as a motor. The drive for dynamo purposes is by belt from the fan pulley and crankshaft. When operated as a motor the engagement is through a pinion which slides on a counter shaft between the armature shaft

and flywheel ring gear and completes the mechanical connection.

The starting switch which makes the necessary changes in connections for charging or starting is located on the transmission case and the operating parts also act to slide the gears into mesh through the action of a stiff coil spring. Should the gears not match exactly, the spring compresses and allows the switch to close when the first movement of the armature under the

Fig. 298
Simms-Huff Motor Dynamo

starting current brings the gears into position and the compressed spring forces them into full engagement.

Regulation of output is maintained at a sufficiently high value (15 amperes maximum) by adjusting the tension of the driving belt. Excess-output is prevented by the differential ac-

tion of the reversed series field winding and by a separate regulator having an electromagnet which acts to insert resistance in the shunt field winding with rise of amperage. This electromagnet regulator is carried in a housing with the cut-out. The output is adjustable by changing the tension of the flat spring.

The cut-out is of the electromagnetic type having two windings and the time of opening and closing is adjustable by a small screw.

Two 6 volt, 35 ampere hour batteries are carried in one box under the front seat, being connected in series for starting and parallel for lighting and charging. A combined lighting and ignition switch is carried; inserting the plug turns ignition on.

Headlight dimming resistance is carried on the engine side of the switch and an ammeter switch and an ammeter is mounted on the dash.

Splitdorf-Apelco Equipment. The electrical unit for these equipments is shown in Fig. 299, and its connections with the balance of the apparatus is shown in the wiring diagram, Fig. 300. The wiring shown applies to the equipment operating at 12 volts for starting and 6 volts for charging and lighting.

These systems use a combined motor dynamo which may also carry an ignition breaker and distributor on a separate vertical head driven from one end of the motor dynamo unit. The system is therefore of one or two unit type, no separate starting motors being used. A

dynamo which does not act as a starting motor is used on the Stanley steam car. All gas cars use motor dynamos.

The unit has four poles, three windings on the fields. One coil is ordinary shunt and acts as

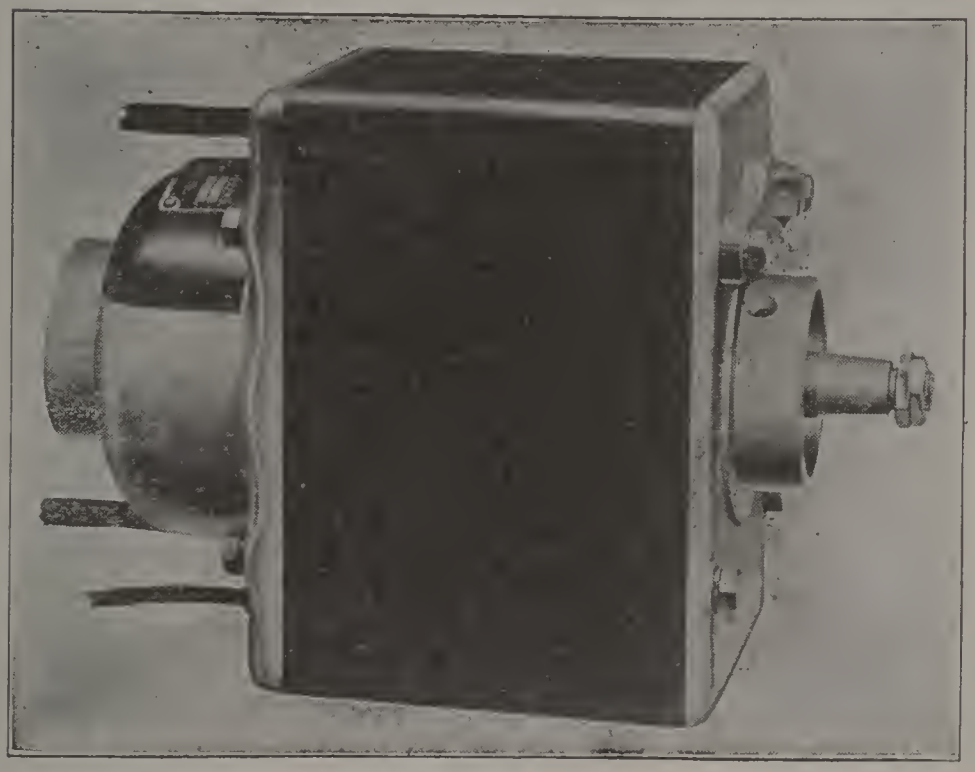


Fig. 299
Splitdorf-Apelco Motor-Dynamo

a shunt in both generating and starting. The output is controlled by a separate bucking coil through which all current from the dynamo passes, this opposing the shunt more and more as the speed, voltage and amperage increase. The third coil is a series winding for starting

motor action, though it also assists the shunt while generating, making a compound dynamo with bucking coil and a compound motor.

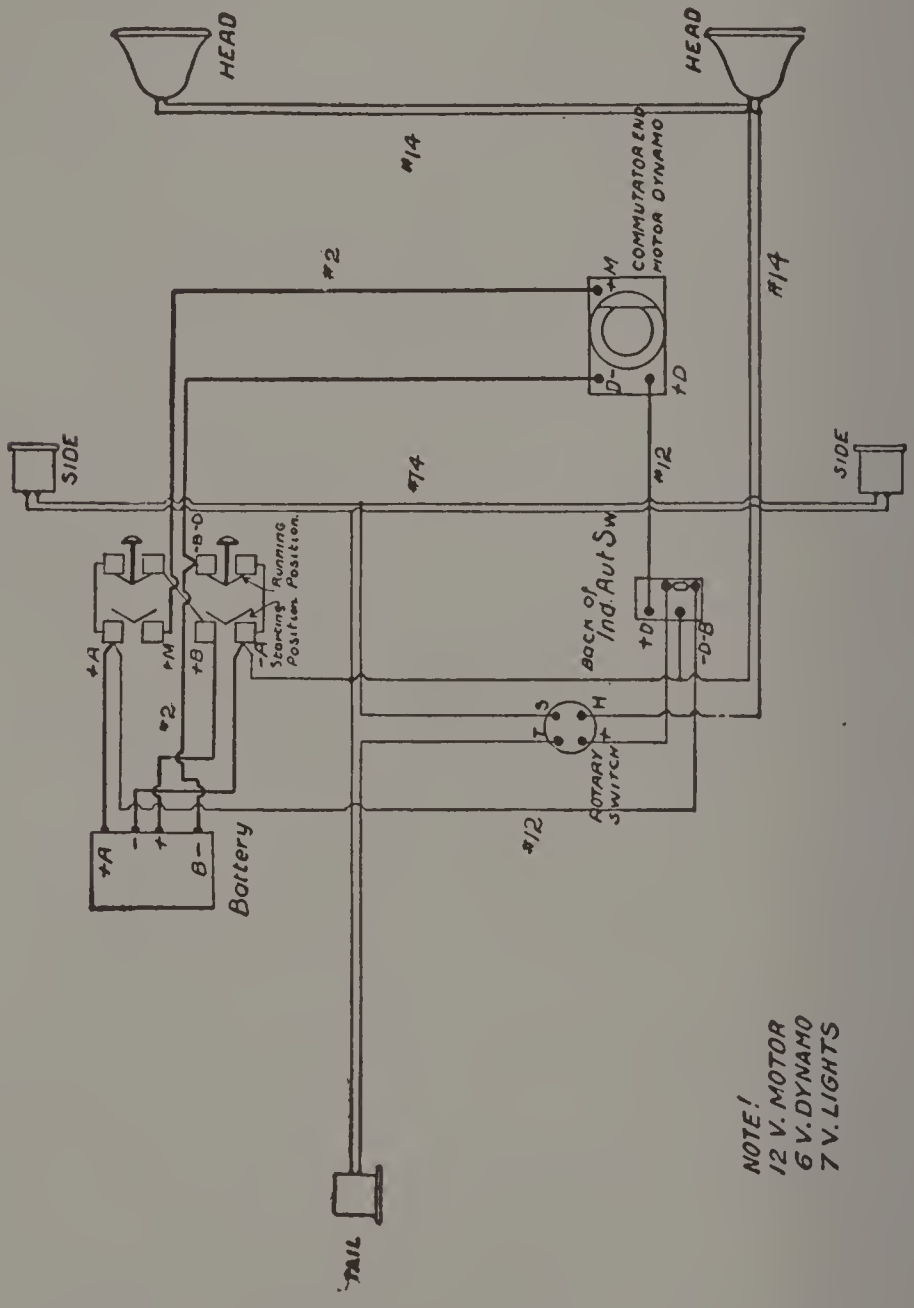


Fig. 300
Splitdorf-Apelco Wiring for 12-6 Volt System

Two voltage combinations are used. One charges the battery and starts on 12 volts, using a six cell battery with all cells in series for

charging, starting and lighting. This is called the straight twelve system.

The other system uses a six cell battery divided in two sections of three cells each and is charged with the two parts in parallel at 6 volts. This system uses all cells in series with 12 volts for starting while lighting is from the parallel connections, thus giving 6 volt charging and lighting and 12 volt starting, the proper connections and changes being made in the starting switch. This is the twelve-six volt system.

Both types use separate electromagnetic cut-outs mounted on the dash in all cases. The cut-out carries two windings. The movable arm carries a marker which shows the word OFF on a dial whenever the contacts are open and the word ON whenever the contacts are closed. ON simply indicates that the current is flowing from the dynamo, but according to the number of lamps turned on it may be going to the battery or to the lamps or may be dividing between them. The engine speed at which the cut-out opens and closes may be changed by a small screw passing through the cut-out spring. This screw may be turned to either lessen or increase the spring tension, thus lowering the cut-in speed or raising it accordingly.

The dynamo without starter action is a four pole shunt wound machine operating at 6 volts. Regulation is with a third brush which carries all the current flowing to the shunt field.

U. S. L. Equipment. Two distinctly different types of equipment have been marketed by the United States Light and Heating Company. The first type, which is described first, was used up to and including part of the year 1915. This type comprises a motor-dynamo mounted on the engine crankshaft with the controlling elements, cut out and regulator, carried in a housing on the driver's side of the dash board.

The type referred to above is known as the "external regulator" type, while the newer system is the "inherently regulated" type. This newer system makes use of a cut out on the dash, but secures regulation of current output by allowing the dynamo current, when excessive, to react on part of the field, and by reducing the field magnetism in proportion to the speed and output, a proper rate of dynamo charge is maintained.

U. S. L. Electric Motor Generator. In the system employed by the United States Light & Heating Co., with which many automobiles are now equipped, an electric motor generator is an integral part of the gasoline motor and furnishes current for starting and lighting. The system includes, besides the motor generator, an automatic current regulator, an oil switch and a storage battery.

The motor generator comprises a set of field coils, armature and commutator and brush ring. These parts replace the flywheel of the gasoline motor, being attached to the crank-

shaft in its stead. They are inclosed in an aluminum case and dust ring.

When a starting button is pressed down, the current from the storage battery starts the

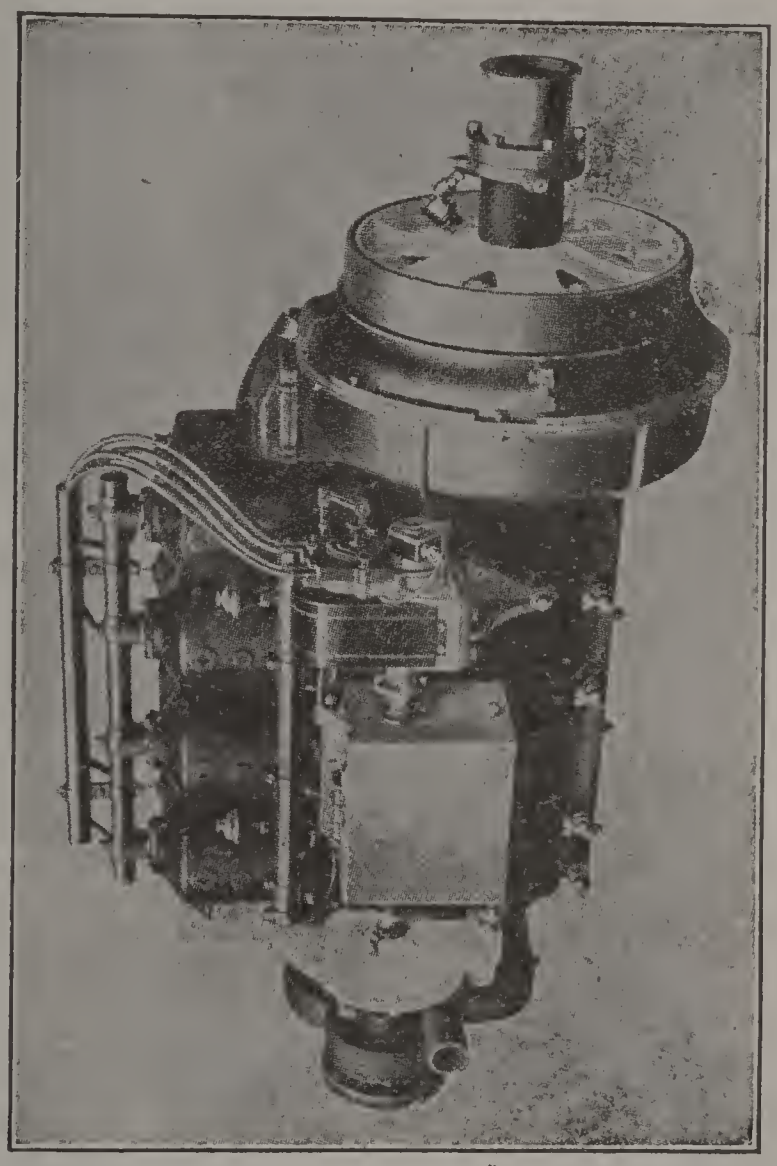


Fig. 301—U. S. L. Gasoline Electric Motor Complete.

motor generator. This revolves the crankshaft of the gasoline motor. With the switch of the ignition coil in either magneto or battery position, the gasoline explosions commence. The foot starting button is then released, when the

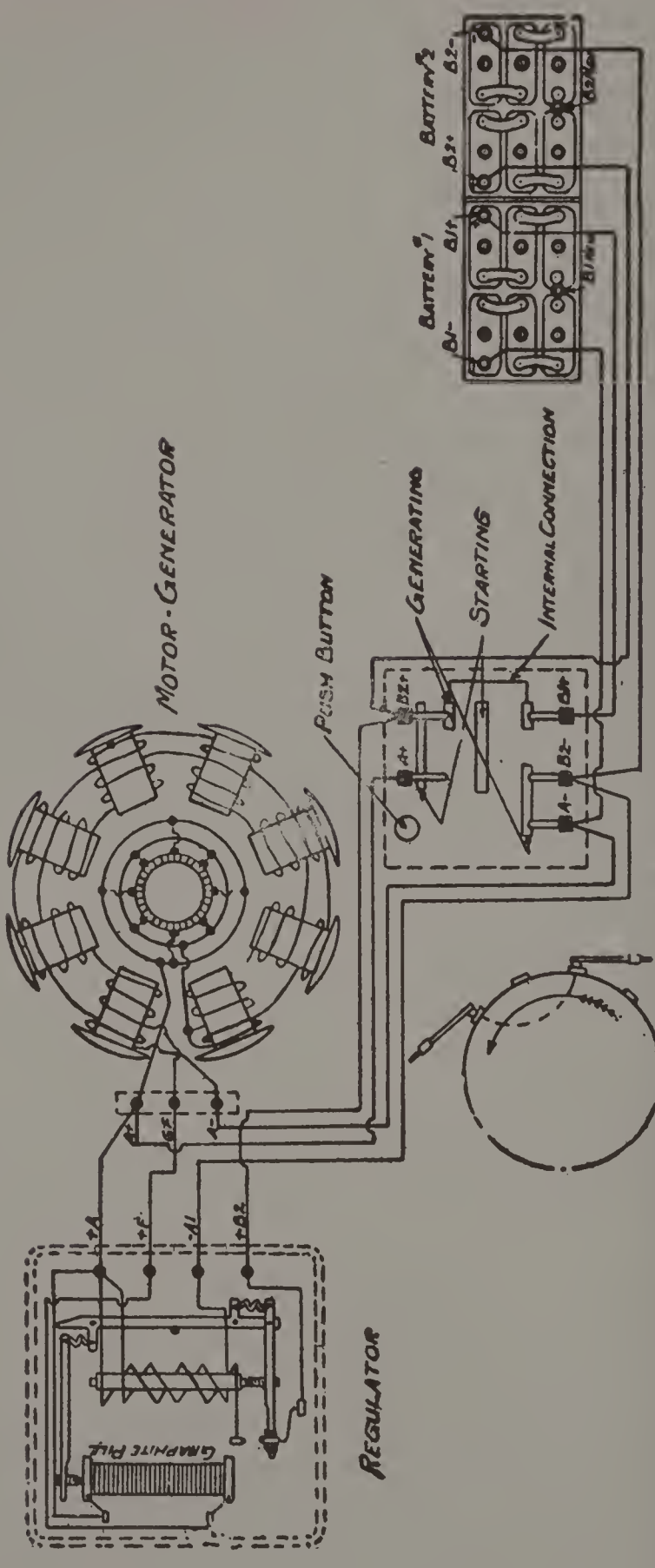


Fig. 302—Wiring Diagram of U. S. L. Starting System.

electric motor automatically changes into an electric generator. As the speed of the gasoline motor increases, the generator gradually begins charging the battery, restoring the current discharged during the starting operation.

An automatic regulator, controlling the current to the battery, is located in the center of the dash. It has a charging indicator, the function of which is to show that the circuit is closed at the proper time, or at a speed of 12 to 14 miles an hour, and that the circuit is open when the car speed drops below about 10 miles an hour or the motor stops altogether. The regulator consists of a compound-wound magnet and a variable resistance with magnet bar and contacts for controlling field current in the generator.

The oil switch is included in this system to change the electric motor into an electric generator upon the release of the starting button.

The type of U. S. L. equipment in most general use at present does not use the externally mounted combined cut-out and regulator but secures regulation of the output as a dynamo by means of a third brush system in which the flow of current through one of the field circuits depends on the current flowing into one of the brushes. The system is known as "Inherently Regulated." An electromagnetic cut-out is mounted on the dash of the car and serves the purpose of connecting the dynamo and battery when the dynamo voltage is suffi-

cient for charging. The complete internal connections for this type of application are shown in Fig. 303.

Above the cut-out are carried two fuses, one of six empere capacity and one of 30 ampere. The six ampere fuse is in the field circuit and will blow out should the battery lines become disconnected with the dynamo operating. The thirty ampere fuse is in the main charging circuit.

The touring switch used with U. S. L. equipment may be opened when the car is used on long daylight runs, and by thus opening the field and charging circuit of the motor-dynamo, excessive battery charge is prevented. The two lamp combinations in use with this type are shown in Fig. 303; one of these being a three wire system with 7 volt lamps, and the other being the usual two wire system with 14 volt lamps. In either case, starting is accomplished with 24 volts and charging at 12 volts, the proper changes in connections being made in the starting switch.

The relative location of the parts of a U. S. L. system having inherent regulation and 12 volt pressure for all functions is shown in Fig. 304.

Wagner Equipment. Wagner apparatus may consist of a combined motor-dynamo with cut-out and starting switch mounted on the unit, or of separate motors and dynamos with a cut-out on the dynamo or mounted separately.

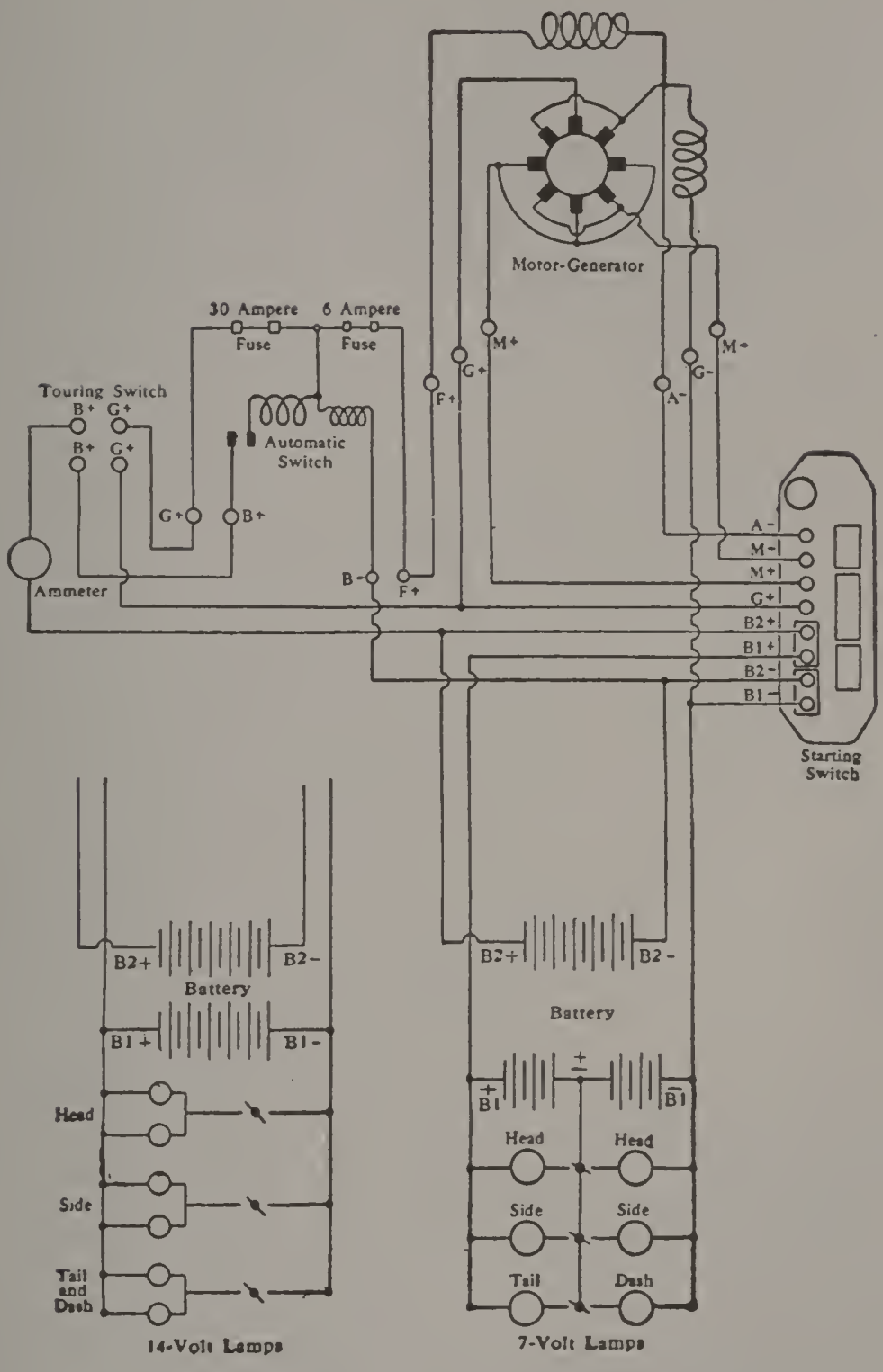


Fig. 303

Internal Connections of U. S. L. 24-12 Volt Inherently Regulated Motor-Dynamo System.

The motor-dynamo is a compound wound machine using the series fields for starting. The output is controlled by taking the shunt field current through a "third brush" which is so placed that excessive amperage is prevented at high engine speeds.

On top of the unit is a housing in which is an electromagnetic cut-out and also a rotary drum starting and charging switch. This switch makes such connections that starting is accomplished with 12 volts pressure by arranging all battery cells in series, while charging and lighting are at 6 volts with the two battery sections in parallel.

The motor-dynamo is driven from the engine by means of a chain to the front end of the crankshaft and is driven from the engine by this same chain. The necessary gear reduction for starting is secured through a planetary form of gearing carried in a housing ahead of the unit, this gearing being brought into play by a brake band that is tightened by the same operation with which the driver moves the rotary switch to the starting position.

If the dynamo, motor and ignition are all separate, the dynamo is shunt wound. Four brushes bear on the commutator, two receiving the main charging current. The other two brushes are slightly nearer together. The second pair of brushes carries the current to the shunt field and because of their location with reference to each other act to decrease the cur-

rent flowing to the field at high speeds because of the distortion of the path of the magnetism

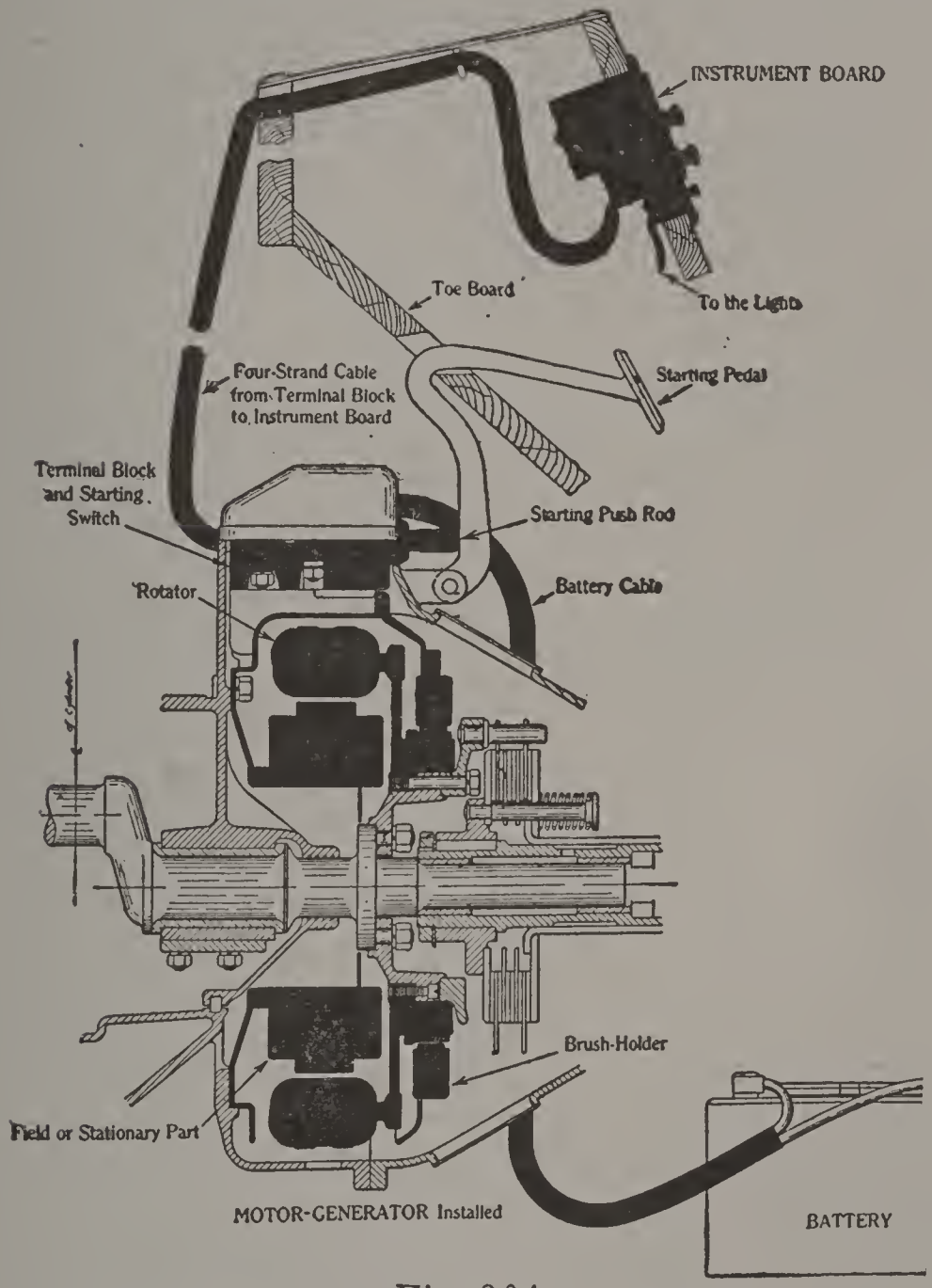


Fig. 304
Arrangement of Parts in U. S. L. Motor-Dynamo System

between the field poles. This regulation action prevents excessive charging rates at high speeds

and causes the output to be slightly decreased at these speeds. The action of this form of regulation is also to increase the output with the increase in battery voltage so that the flow is greater to a battery when nearly charged than when nearly empty.

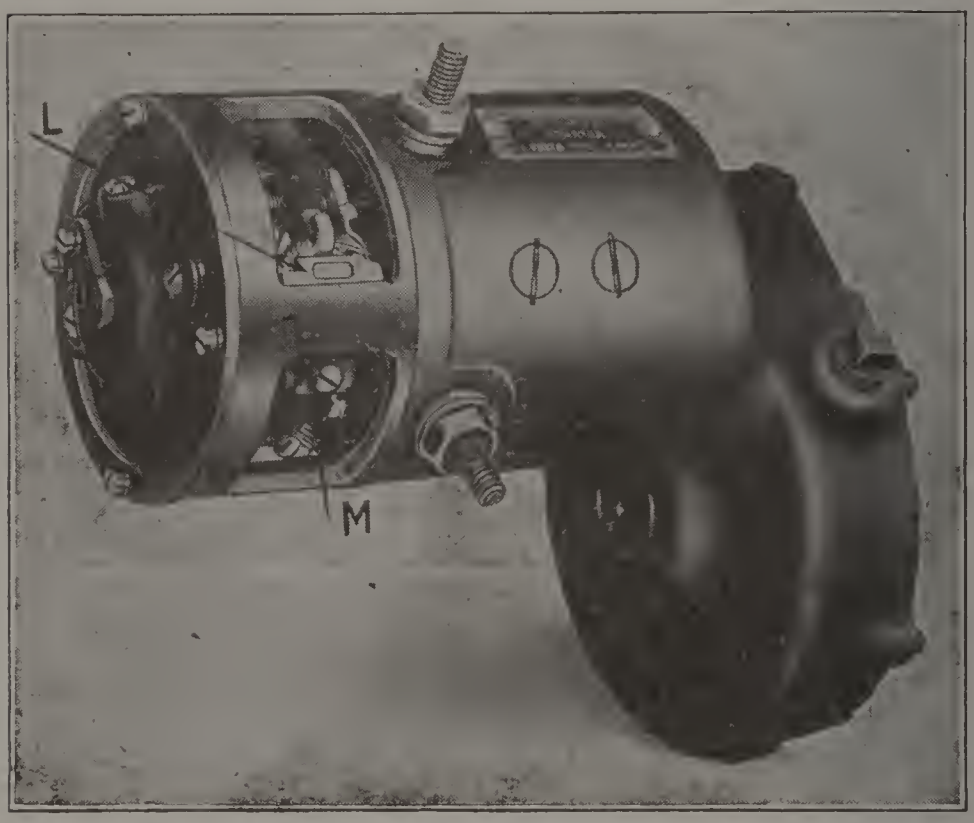


Fig. 305
Wagner Starting Motor With Gear Reduction
L and M, Brush Holders

The starting motor, Fig. 305, drives through a spur gear reduction and chain to the front end of the crankshaft. An overrunning clutch is built into the sprocket on the crankshaft. The starting switch makes the circuit complete without any preliminary resistance, the clutch providing the engagement.

Westinghouse Equipment. Three distinct types of Westinghouse apparatus are in use. The first, and oldest, type makes use of a separate dynamo securing output regulation by means of a bucking coil field as described in the following pages, and having an electromagnetic cut-out mounted on the dynamo. Another type includes a separately mounted dynamo having a vibrating reed voltage regulator and an electromagnetic cut-out mounted on the dash board or inside of the dynamo housing. The third type consists of a combined motor-dynamo having third brush regulation.

In generating current the machine acts as a shunt wound dynamo, the reversed series coil acting to regulate the amperage in a way peculiar to these systems. One end of the reversed series coil is connected to one of the dynamo brushes in such a way that current flowing into the battery for charging passes through this coil and by opposing the shunt winding keeps the amperage down to a proper point. The line which leads to the lamps from both battery and dynamo is attached to a lead from the differential winding in such a way that current from the dynamo to the lamps does not pass through the bucking coil. That means that the amount of current which flows through the bucking coil with the lamps off is the entire amount from the dynamo going to the battery, but as soon as the lamps are turned on a part of this current passes to the lighting

lines and no longer goes through the bucking coil. The reduced flow through the bucking coil with lamps on allows the shunt field to exert its effect without so much opposition and the output accordingly rises to care for the additional lamp load. Should enough lamps be turned on to take the entire dynamo current, none will be left to the bucking coil and the dynamo will act as a shunt machine without opposition and give the fullest current flow of which it is capable under these conditions. Should still more lamps be turned on the additional current will flow to the lamp lines from the battery through the differential wind-

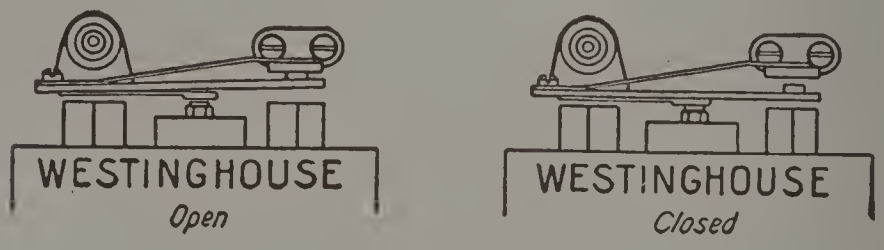


Fig. 306
Westinghouse Cut-out Used With Inherently Regulated Dynamos

ing, but in an opposite direction from which it passed in bucking the shunt action and will therefore serve as an additional series winding assisting the shunt and the machine is therefore compound under these conditions and the output is still further increased.

All dynamos of this type carry an electromagnetic cut-out, Fig. 306, on the dynamo housing at the drive end just above the shaft, the

magnet carrying two windings as is the usual practice. This cut-out should close at about 8 miles per hour and re-open at about 6 miles per hour. It has no means of regulating the time of opening and closing. The wiring for this system is shown in Fig. 307.

The dynamo having voltage regulation is of the shunt wound type and the regulator acts to insert a resistance in the field when the terminal voltage rises to the predetermined limit. The operating parts of the combined cut-out and regulator are shown with the cut-out open in Fig. 308, and with the cut-out closed in Fig. 309. The complete internal connections of the voltage control dynamo with self contained regulator and cut-out are shown in Fig. 310.

When the dynamo is being operated at a speed below the predetermined "cut-in speed", the contacts of the cut-out armature are open, the voltage of the dynamo being below that of the battery. When the speed reaches the "cut-in speed" these contacts are closed, connecting the dynamo circuit to the battery circuit. The "cut-in speed" varies from five to ten miles per hour on high gear, depending upon the gear ratio and wheel diameter of the particular car.

The "cut-in speed" can be observed by running the car, allowing it to increase in speed

slowly, and observing on the speedometer the speed at which the car is running when the cut-out contacts close, which is indicated by a slight movement of the meter needle.

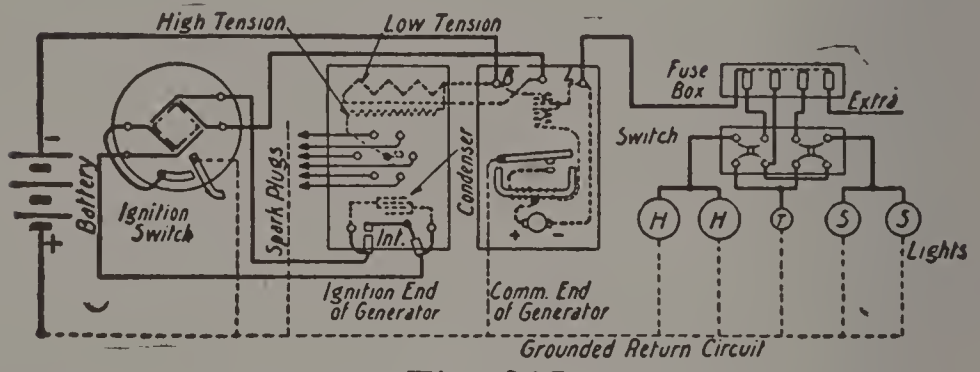


Fig. 307

Wiring of Westinghouse Ignition and Lighting System, Inherently Regulated

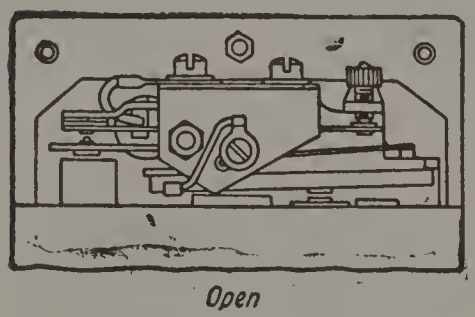
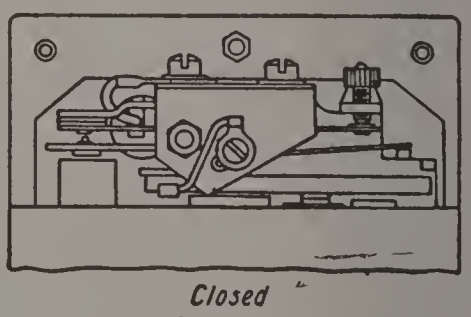


Fig. 308

Westinghouse Voltage Controller, Cut-out Open



Fige. 309

Westinghouse Voltage Controller, Cut-out Closed

The regulator is so constructed that the cut-out operates to disconnect the dynamo from the battery circuit at a speed slightly below the "cut-in speed". This enables the cut-out to

keep the circuit closed, and not constantly open or close it when the car is being run at speeds

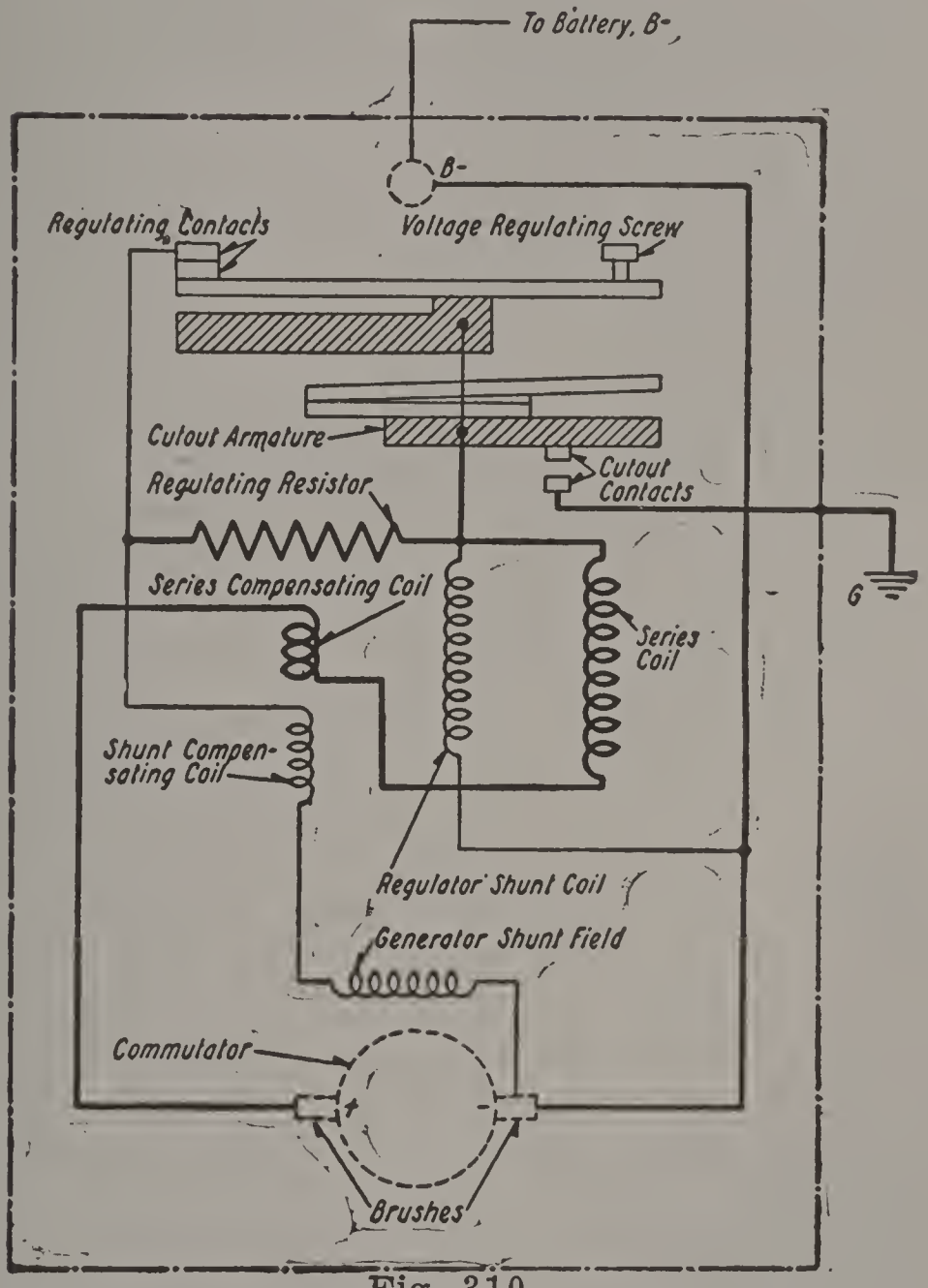


Fig. 310

Internal Connections of Westinghouse Self-Contained Voltage Control Dynamo

close to "cut-in speed". This disconnecting of the dynamo from the battery circuit when

the dynamo voltage is below the battery voltage insures that the battery will not be discharged through the generator.

The shunt fields of the dynamo are so designed that a voltage in excess of the normal voltage would be regularly generated when the dynamo is operated at high speed and no load. This excess voltage is prevented and the voltage is held constant by the automatic voltage regulator. When the dynamo is operating below "cut-in speed" the contacts of this regulator are closed, and remain closed until the armature is revolved at a speed which generates a voltage in excess of a predetermined value. This voltage is fixed by the setting of the voltage regulating screw which is adjusted at the factory. When, due to the increased speed of the dynamo, the voltage tends to exceed the value for which the regulator is set, the regulating contacts open, opening the direct shunt-field circuit and cutting in the regulating resistance. This causes a momentary drop in voltage so that the contacts close again. This opening and closing of the contacts is continuous, and so rapid as to be imperceptible to the eye.

Dynamos are also furnished with ignition parts carried on one end of the dynamo frame, these parts consisting of a magneto type breaker which automatically advances the spark by a pair of governor weights acting as the breaker cams and a distributor mounted above

the breaker. Otherwise the unit is the same as the dynamos described.

The combined motor dynamos are four pole compound wound machines operating with 12 volts, while the electromagnetic cut-out may or may not be employed. When the cut-out is used it is carried as a separate unit. These machines drive to the crankshaft direct through chains or gears without the use of overrunning clutches.

Almost all Westinghouse installations use the single wire system with the positive side of the circuit grounded in all cases. The ground return for the starting motor is assisted by having the cable enclosed in copper tubing which is attached to the metal work of the car and which is therefore free to carry the current to the motor.

The lighting switch is usually of the push button type. All circuits are fused, the cartridge fuses being carried in fuse boxes which provide for 3, 4 or 5 circuits in addition to the line to the battery. The fuse for head and tail lamps should be 15 ampere, for side and tail 5 ampere, for tail alone 3 ampere and for additional circuits such as the horn 15 ampere. When 6 volt bulbs are used with short wiring one of the fuses is replaced with a coil of resistance wire so that the voltage to the lamps with short connections may not be excessive. With 7 volt bulbs this compensator coil is unnecessary. Head lamps may be dimmed by

throwing them in series or by arranging a restance coil in one lead to the lamps. Junction boxes are used to centralize the connections and disconnector blocks are used for allowing body removal. Either an ammeter or voltmeter may be used, the ammeter being connected on one of the battery lines to the lamps and dynamo in the usual way while the voltmeter is directly connected to the two sides of the battery, indicating the voltage at all times. The current drawn by the voltmeter is so small that it can be neglected in every way.

Separate starting motors are of the four pole type, series wound with the field coils carried on two of the four poles, and operate with 6 volts.

Starting motors may drive the engine in any of five different ways. One system drives from a pinion on the armature shaft to a larger spur gear on a counter shaft, this larger gear having an overrunning clutch built into it. Mounted on the counter shaft is a small pinion which is free to slide on the counter shaft until it meshes with teeth on the flywheel rim. This sliding pinion is moved by a yoke and rods from the foot pedal, these operating rods also operating the switch. The first movement of the pedal closes the circuit through preliminary contacts and resistance ribbon, causing the starting motor to whirl with little power. Further movement of the pedal breaks this electrical connection but leaves the motor spin-

ning while the movement pulls the gears in mesh. After the gears are meshed the switch has traveled to a position in which full contact is made and the motor turns the engine. Releasing the pedal opens the switch and the gears are thrown out of mesh by a coil spring in the gear housing.

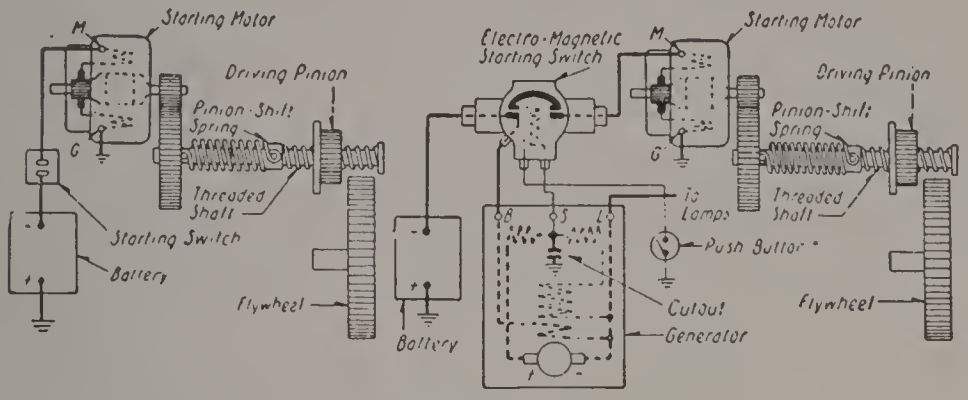


Fig. 311

Internal Connections of Westinghouse Magnetic Pinion Shift Starting Motor Drive

Another system uses the same arrangement of gearing between armature shaft and flywheel teeth but the gear meshing and closing of the switch is accomplished by solenoid action in place of by foot power. Three switches are used, Fig. 311, one being a push button on the dash marked "start," another being a small cylindrical housing through which the large starting cable runs and to which the wire from the dash button also leads and the third being the starting switch which is connected to the shifting pinion as previously described.

Pressing the dash button allows current to flow from the battery to the small cylinder-shaped switch and through the windings of a magnet on this switch. This magnet pulls the contacts closed which allow the battery current to pass through and to the large starting switch. The large switch contains a powerful solenoid coil through which the current then flows and out through a small auxiliary wire to the ground. The solenoid immediately pulls on a plunger which is attached to the sliding gear and starting switch contacts and the action of closing the contacts and sliding the pinion into mesh is done by the pull of the solenoid in the same way as previously described for the foot button action. As soon as the engine starts it runs the dynamo and the voltage of the dynamo rises to a point equal to the battery voltage. This balance of pressure prevents any more current from flowing through the switch operated from the dash button and the main starting cable contacts open whether the dash button is released or not. This kills the solenoid action and all parts return to normal positions.

The starting motor may also drive to the crankshaft through gearing or chains with overrunning clutch in which case the starting switch makes full contact in the first position.

Some installations drive to the flywheel by means of a Bendix type of application.

Steering Gear—Principles of. In steering gears the generally accepted principle is that known as the Ackermann-Jeantaud, which was invented in 1878 and is a modification of the

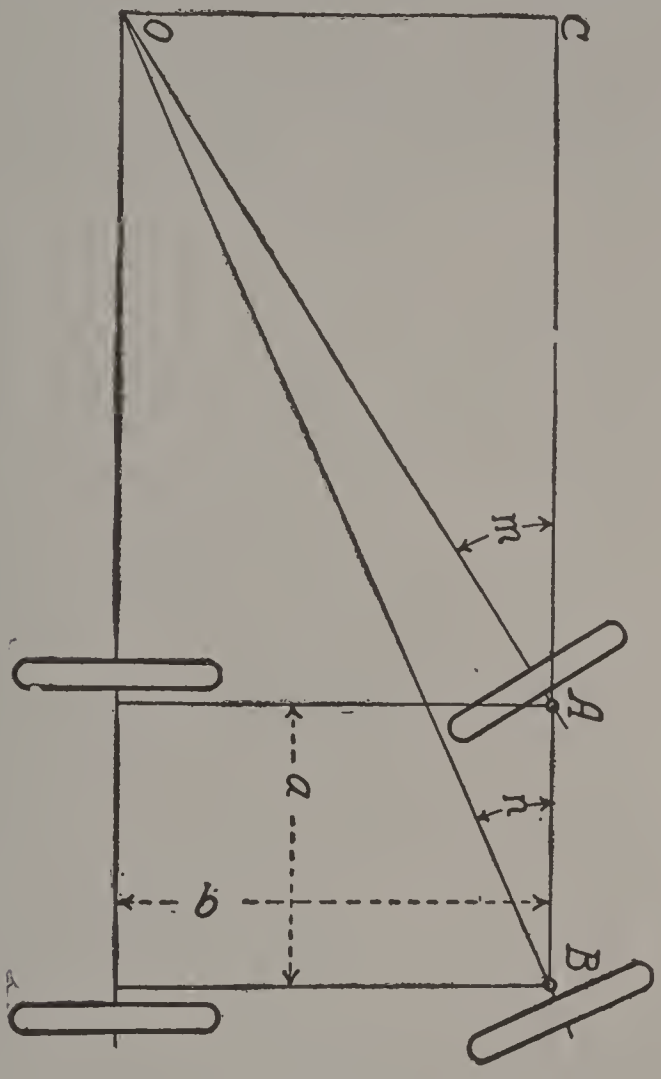


Fig. 312
Designing Steering Knuckle Arms

original Ackermann principle. In the Ackermann-Jeantaud system the steering knuckle arms OL and O^1L, when produced, meet in the plane of the rear axle or in this plane produced as shown by illustration, Fig. 313. The reader will appreciate that when the tie-rod L L is in

rear of the front axle, the steering knuckle arms, OL and O¹L converge, as illustrated, but should the tie-rod be in front of the axle, these arms diverge. Strictly speaking, the points A and AI, which are supposed to be in the axle

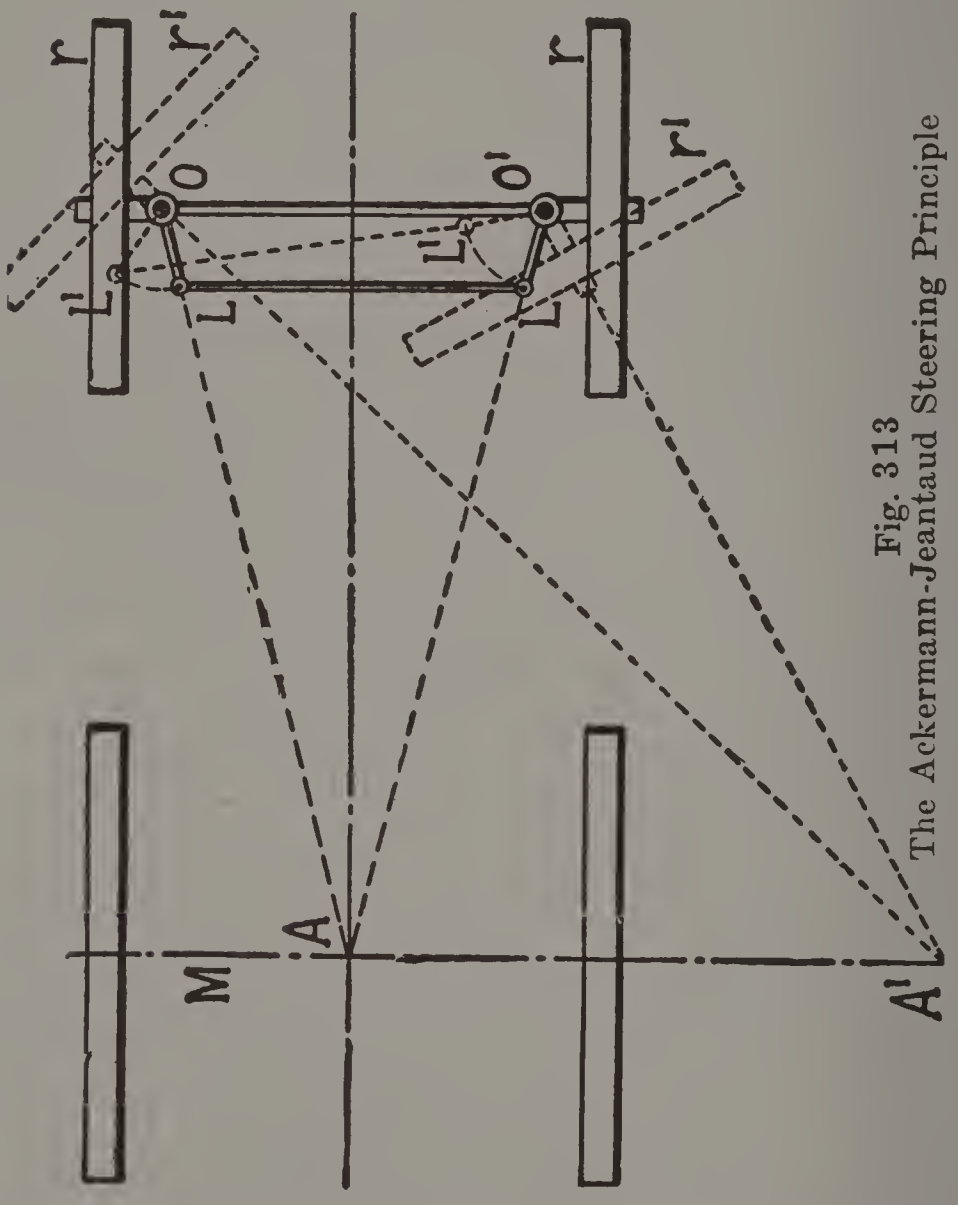


Fig. 313
The Ackermann-Jeantaud Steering Principle

plane, are not so, and the axle line A, AI, is a tangent to the curve in which the points of convergence will fall in a complete sweep of the steering wheels from axle to axle.

It will be realized from the foregoing explanation that the dimensions and proportions of the steering axle parts depend on the wheelbase of the car, inasmuch as with a longer wheel base the distance that the lines would be produced would be greater with the increase.

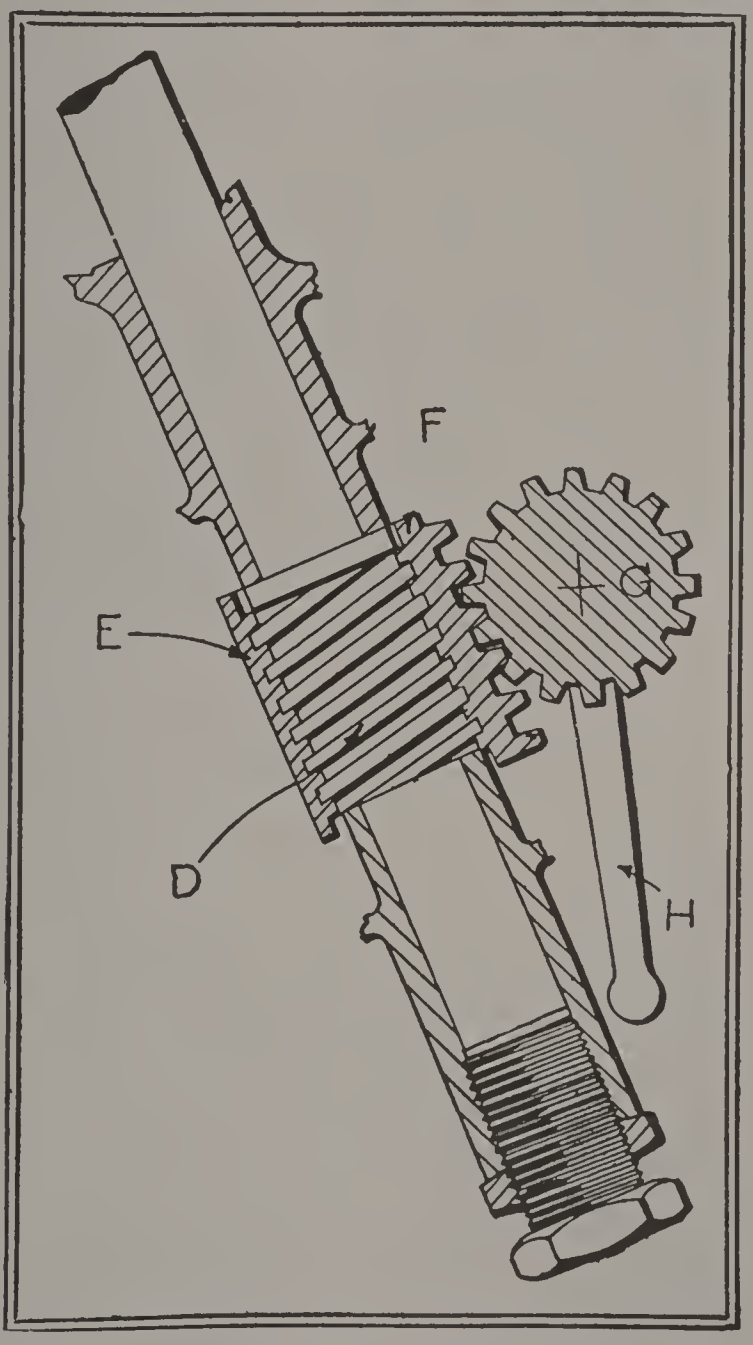


Fig. 314

Several makers have, however, discontinued the design of steering knuckles on this principle, preferring to design them as illustrated in Fig. 312, in which the produced axis of the front wheels, A and B, intersect the axis of the rear wheel at a given point O. With this condition fulfilled, the vehicle will travel around O as an imaginary center. Enthusiasts of this method of construction agree that the Ackermann-Jeantaud principle is sufficiently accurate for angles of not more than 30 degrees, but for angles varying from 30 to 45 they claim less wear on their tires by the latter construction. The exact arm for the angles in a steering gear of this nature will depend largely on the wheelbase of the car as well as the difference between the steering pivots A and B.

Steering Gear—Types of. Fig. 314 shows a sectional view of the nut and segment type of steering gear, in which there is a worm D on the steering column that engages with the nut E. On the front or gear face of the nut is a rack F which meshes with the sector G, so that as the steering wheel is turned right or left the nut is raised or lowered and the requisite movement imparted to the radius rod H. In certain screw and nut steering gears the sector is not required, the construction being a screw on the steering column on which works the internally threaded nut, and on either side of this nut are trunnions with links which connect with the axis carrying the radius arm.

Steering Gear—Lost Motion in. If the gear is of the worm and sector type it may be that these two elements are not held in the proper relation to each other. Fig. 315 shows a diagram of this type of gear, and illustrates plainly the point where lost motion will be of the greatest detriment. When the wheel is turned, if there is the slightest end play, the wheel shaft

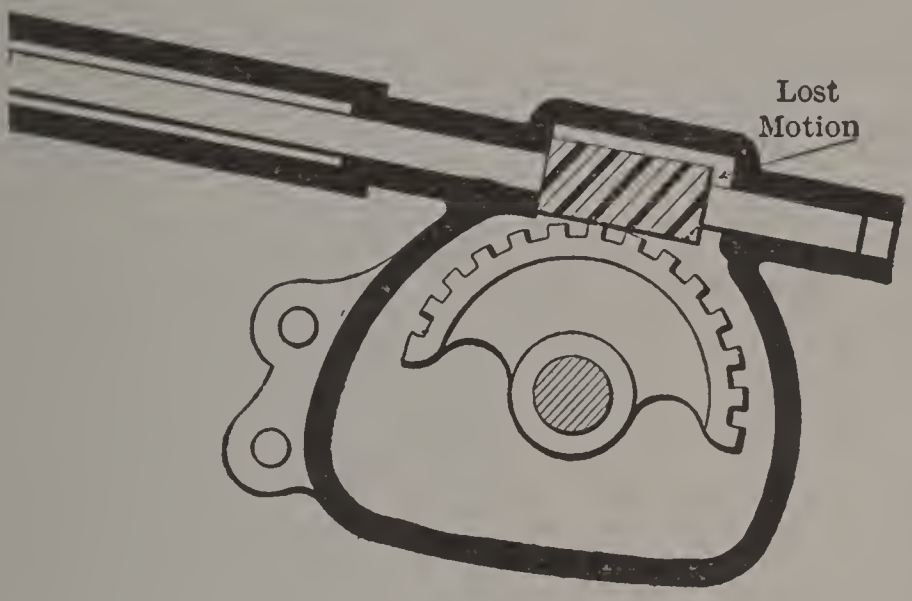


Fig. 315

will respond, but the geared sector will not, until all the end play is taken up, and as strains come on from the road wheels, the sector will rotate to and fro, causing the shaft of the steering wheel to reciprocate and thus allow the road wheels to wobble. To overcome this it is necessary to replace the thrust washer, if there be one, and if necessary, introduce a

washer, made of phosphor bronze, of suitable thickness to take up all the end play of the steering wheel shaft.

Some lost motion will follow if the worm is not set on the pitch line, in its proper relation to the sector; this will be true if the bushings are worn, and when a new thrust washer is made and fitted into place, if the lost motion is still greater than is desired, the only thing remaining is to replace the bearing brasses. When the gear is dissembled it will be possible to dimension the same, and determine by measurement if there is any great amount of journal wear, thus rendering the task less troublesome, since the brasses may be replaced without waiting to determine the remaining lost motion through actual trial.

As a rule, it will be found that the lost motion is due to end play, just as the illustration shows, and not to worn-out journal brasses on which the wear is far less than it is in thrust. If the gear is irreversible, or nearly so, as it is in many automobiles, a little lost motion is to be expected owing to the smallness of the angle of the worm, which can only be irreversible if the angle is such that a little lost motion will be present and unavoidable.

Care of Steering Gear. The steering gear is a very important part of the car, and, as the safety of the occupants may be endangered by any binding, the autoist should give it even more careful attention than the other parts.

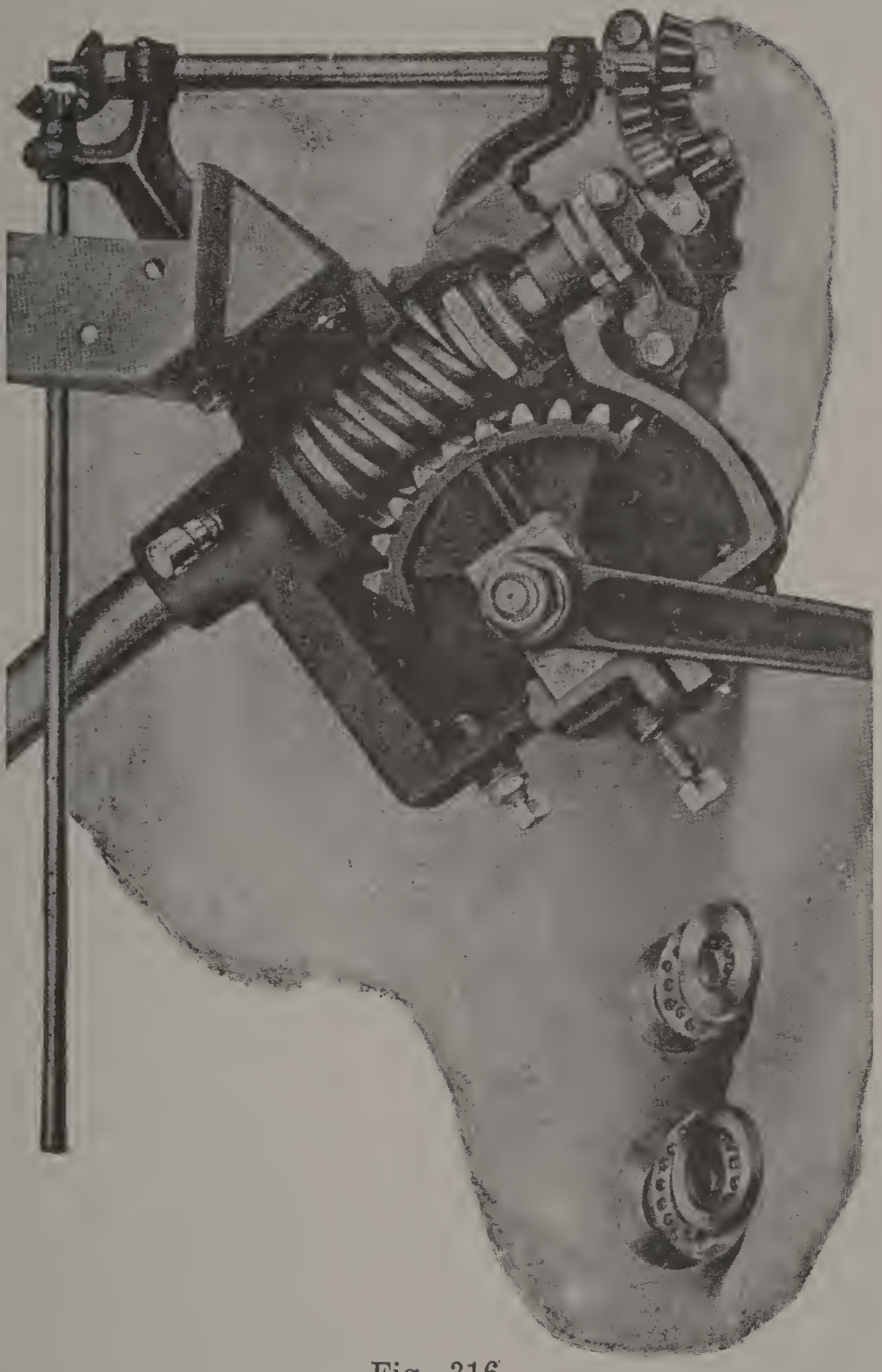


Fig. 316
Worm and Sector of Steering Mechanism

The gear should be taken down, given a thorough cleaning and examined for possible wear.

In case the steering action is stiff and the wheel turns hard, the ball joint may be out of adjustment due to wear; the steering link may be bent, or the cause may be insufficient lubrication. If there is any considerable amount of backlash, the cause may be looked for in the joints of the levers, in the swivel pin, or in loose bearings.

Tires, Care and Repair. Aside from gasoline the greatest expense in the upkeep of a motor car is the tires, and much of the present excessive tire wear may be reduced with reasonable precaution and care. There are ten common tire diseases, as follows: wheel out of alignment, under-inflation, use of anti-skid chains, skidding, running wheels in car tracks, neglect of casing repairs, tread cuts, running in ruts, stone bruises, use of inside protectors on new tires.

When a tire is on a wheel which is out of alignment the result is that the tire is scraped across the surface of the road and the resulting friction causes the tire tread to wear rapidly. The action of the tire on the road is crosswise at the same time that the tire revolves with the wheel. Thus the tire receives its usual wear plus the wear due to the scraping. The tread of a tire which has been run on a wheel out of alignment presents a rough appearance, that which would be given it were the tire held against an emery wheel for a while. Sometimes the fabric shows in places, and this is especially

true of wheels which are wobbly. It is advisable to line up the wheels of a motor car about every three months, and if one is found which does not run true, the condition should be corrected immediately.

Perhaps as much harm is done by running a tire under-inflated as by anything else. Under-inflation, as the name implies, means that the tire is running with insufficient air pressure. Such a tire appears usually with a series of hilly blisters running around the tread. The blisters are caused by the separation of the fabric from the tread due to the excessive heat generated in an under-inflated tire. With insufficient air the flexing of the walls of the tire causes heat to be generated and this heat acts on the cement between the tread and fabric and in a short time the two separate, causing a blister to appear. Even in the summer a tire should not be run under-inflated. The common version is, that if the ordinary pressure is 80 pounds, a reduction of possibly ten pounds is made for summer weather. The belief is that the heat of the atmosphere will soon raise the temperature of the air in the tire and thus cause the pressure to increase to the proper point. This practice is not advisable, as there is undue wear on the tire while the pressure is being increased by the rise in temperature, and also because the pressure will drop as soon as the tire cools. The cure for under-inflation need hardly be stated. Keep the tires inflated to the pressure specified by

the maker, which is usually 20 pounds per inch of cross-section. Thus, a 4-inch tire should carry 80 pounds pressure. It matters not if the pressure is a little more, but it does if the pressure is less than that for which the tire is designed. A tire guage, such as is sold for one dollar, should be one of the important instruments in the motorist's tool kit.

When anti-skid chains are applied to the tire too loosely or too tightly, the result sometimes is a cut tread. These chains should be placed on the tire so that they fit snugly and then no material tire wear will result.

Running a wheel in car tracks may soon cause the sides of the tire to become chafed, and in some instances the wear is so much that the tread loosens at the sides and begins flopping around. The same appearance may result if the car is driven very close to the curb and the side of the tire made to scrape the stone.

Little cuts in the casing often result in the casing being unfit for use in a short time. When a small cut appears and the tire is operated, dirt and water get underneath the tread. This dirt works its way around the tire under the tread with the result that the tire is soon loose. Water, as everyone knows, is detrimental to rubber, and more so to the fabric. Fabric begins to rot in the presence of water. The small cuts may be plugged with mastic.

Often a cut appears in the tread and an inspection finds that the fabric is injured also.

In such an instance the blowout patch is the first resort. The patch, if wrongly applied, sometimes becomes wedged in the fabric cut and in this way hastens a blowout. The best way to treat a tire with a reasonably large tread cut is to have the cut vulcanized immediately. In fact, even small cuts should be vulcanized at the first opportunity. The owner may say that the cost of having the tire vulcanized every time it is cut is expensive. It may seem expensive at first, but the saving in tire wear and repair later overbalances the comparatively small cost of vulcanization.

In the fall especially country roads present a mass of hardened ruts which play havoc with tires. These hard indentations house the tire for a while and then the driver will go over the rut. The driving in and out of these ruts creates a condition which puts a tire in the rut-worn class. The sides of the tread begin to show rapid wear and sometimes the wear is great enough to cause a weak spot in the tread, with the result that the tire blows out.

Stone bruises cause a great percentage of tire failure. When a tire runs over a stone, one as big a man's fist, there is a possibility of the fabric becoming broken. A broken fabric soon causes a blowout, so it remains for the driver to prevent as far possible running over such stones. Small stones sometimes present sharp edges which cut the tread and thus make an entrance for dirt and water. Stone bruises are

hardly visible from the outside, as the condition is one of a fabric break, as mentioned above. The result of a stone bruise may be seen by examining the inside of the casing, which will show clearly that the fabric is injured.

Some makers state that the use of inside protectors on new tires is not advisable, as these appliances create an undue amount of heat in the tire and thus hasten wear. For old tires the inside protector is perhaps the best accessory marketed for lengthening tire life. Some owners have obtained as much mileage with old tires and inside protectors as they have from new tires operated without protectors.

Tire Vulcanizing. Absolute cleanliness is necessary in all vulcanizing work. No matter how good a vulcanizer you have or what kind of repair stock you use, the smallest amount of oil, grease or dirt will greatly impair the work. Therefore clean every repair thoroughly with a cloth or brush dipped in clean gasoline and roughen the point of repair with a rasp or coarse sandpaper while still wet.

Tires must be dry before beginning work on them, otherwise a porous patch will result. If you think, for any reason, that the canvas in the casing is even slightly damp, clamp the vulcanizer loosely over the tire for ten or fifteen minutes before applying the first coat of cement. Interpose a piece of waste or something of the sort between vulcanizer and tire to permit the escape of moisture.

It takes from fifteen to twenty minutes to vulcanize a layer of Para one-sixteenth of an inch thick if the thermometer is kept at 265 degrees, and five additional minutes for each additional sixteenth of an inch. Vulcanization will occur equally well at all temperatures between 250 degrees and 275 degrees. The lower temperatures require more, and the higher temperatures less time than stated above.

Inner tube punctures. Clean the tube thoroughly with gasoline and coarse sandpaper, for at least an inch all around the hole (be careful not to get gasoline inside the tube); then wipe with a cloth moistened with gasoline. When the gasoline has evaporated cement the edges of the hole and apply a thin layer of cement to the tube for three-quarters of an inch on each side of the hole. Let the cement dry until the gasoline has all evaporated and the cement is solid enough to resist the touch. "Tacky" is the usual word. Apply a second coat and let dry as before.

If a small hole, fill even with the surface of tube with layers of Para rubber cut the size of the hole, taking care that the Para sticks all around the edges. If a simple puncture, place a narrow strip of Para rubber over the end of a match and insert it into the hole. Cut off what protrudes outside the tube. Cut a patch of Para one-eighth larger than the hole or puncture and apply over same. Then cut another patch one-half inch larger than the hole and

apply over the first. Cover and apply vulcanizer.

Repairs of this sort are to be vulcanized for fifteen or twenty minutes at 265 degrees.

Inner tube cuts and tears. Clean as directed both inside and outside of tube; coat edges of cut and inside and outside of tube with cement and let dry. The cement should extend three-fourths of an inch back from the cut.

Cut a strip of Para rubber as wide as tube is thick and stick on edge of cut; cut a strip one-half inch wide of Para rubber cured on one side, place it inside of tube under tear with cured side down, bring edges of tear together and stick them down to this strip. If you do not have any of the Para cured on one side regular Para may be used after cementing a piece of paper to inside of tube opposite the cut to prevent patch from sticking to opposite side.

Apply another strip of Para rubber one-half inch wide on the outside of the repair. Vulcanize for twenty-five minutes.

The first step in making a casing repair is, just as in the case of all tire work, to thoroughly clean the point of repair. Apply from one to three layers of cement, allowing each to dry. If the canvas is exposed, as in a scalp cut, put on enough cement to fill the pores of the canvas and leave a smooth surface when dry. Fill the hole not quite level with surface with Para rubber. The best results are obtained when casing repairs are slightly concave. If filled too full,

the rubber will expand and flow over onto the unprepared surface in a thin film that will soon peel up and cause trouble. Moreover, a protruding patch will receive more than its share of hammering and will undoubtedly split open.

Tonneau. The name or term used in connection with the rear seats of a motor car. Literally the word means a round tank or water barrel.

Torsion Rod. When the manner in which the power is transmitted from the change-speed gear to the rear axle on the shaft-driven car is considered, it will be apparent that the turning of the shaft imposes a twisting strain on the whole rear end of the car, and that if it were not for the frame, and the weight of the car on the ground, there would be a tendency to revolve the rear of the chassis around the shaft, rather than to turn the wheels. But it would be bad practice to permit this strain to fall on the frame and hence the office of the torsion rod, which is designed to prevent its reaching that member. On cars that are not provided with independent torsion rods, it will be found that the housing of the propeller shaft has been made correspondingly stronger, and that its support has been designed to enable it to act in this double capacity. This represents a simplification of design that will be found on quite a number of cars, as it eliminates a part exposed to mud and dirt.

Traction of Driving Wheels. A horse which

exerts a pull of about 375 pounds continuously for an hour and goes a distance of one mile in an hour is working at the rate of one horsepower. If for any reason the horse is unable to exert as much as 375 pounds pull when going at the rate of one mile per hour, he is thereby prevented from working at the rate of one horsepower.

The same rule applies to a motor car. When the road is not slippery there may occur a condition which does not appear with horse traction; that the tires fail to adhere to the ground owing to insufficient weight on the driving wheels. In such a case it is impossible for the motor-car to exert a push of 375 pounds without skidding the wheels, and thus it would be impossible for it to work at the rate of one horsepower. With underpowered motor-cars this difficulty does not occur, but to develop 10 horsepower at the rims of the driving wheels while covering the ground at the rate of one mile per hour, the car must exert a push on the road of 3,750 pounds. This is, on touring cars of ordinary weight, impossible, because the weight on the driving wheels is invariably less than 3,750 pounds, while the adhesion with the road is only a fraction of the weight on the rear wheels. As the speed rises, however, the push necessary for the development of 10 horsepower goes down until at 10 miles per hour a push of 375 pounds means 10 horsepower.

Thus a 40 horsepower car, if it could start

work with the activity of forty horses, would, while it was moving at one mile per hour, exert no less a push than 40 x 375, which is equal to 15,700 pounds. This tremendous push is rendered impossible by the fact that the wheels of a car weighing 2,000 pounds only grip the ground enough to exert about 750 pounds push. Beyond this point they will skid.

This shows that a high-powered car, when the car is moving slowly, cannot develop its full power unless the road wheels are capable of adhering to the ground sufficiently to transmit this power. As a rule only about 0.6 of the weight of the car is on the driving wheels, and of that only 0.625 is available for the adhesion (owing to the coefficient of friction between rubber and road being 0.625). So a 10 horsepower car weighing 2,000 pounds cannot exert its full power when the car is starting, nor until it is traveling at 5 miles per hour.

It would be wrong to contend that on all cars having the weight distributed as at present, a 60 horsepower motor is useless, but it is needless to say that the output of such a motor is not availabe at starting or at any speed under 30 miles per hour, although the whole power is more needed then than at any other time. The remedy which suggests itself is by using all the adhesion of the car, that is, to drive with all four wheels.

Transmission of Power—Efficiency of. The efficiency of various forms of drives between

the motor and the driving wheels of a motor car may be estimated as follows:

Single-chain, with direct drive on the high speed, between the motor and rear axle—85 per cent.

Two-chain drive, from motor to speed-change gear, from speed-change gear to rear axle—75 per cent.

Quarter-turn or right-angle drive, with double-chain drive to free rear wheels—70 per cent.

Longitudinal shaft drive, with universal joints and bevel gear in differential case—65 per cent.

Transmission Shaft. The square transmission-shaft used on several highest-powered cars is a nickel steel forging with .25 to .30 per cent of carbon. The treatment is about as follows: First heated in lead bath, then transferred to the cyanide, where it remains 20 minutes, then dipped in cottonseed oil. The shaft then goes to the furnace and is heated to 1,400 degrees Fahrenheit. When removed from the furnace, only the part of the shaft upon which the sliding gears operate is dipped in oil. This class of steel before treatment averages 86,000 tensile strength, after treatment 125,000 to 130,000.

Transmission. See *Change Speed Gearing.*

Trouble Location. See *Knocking, Pounding, Preignition, etc.*

Twelve-Cylinder Engine. See *Engine, Eight and Twelve Cylinder.*

Unit of Heat. The heat unit or British thermal unit (B. T. U.) is the quantity of heat required to raise the temperature of one pound of water one degree, or from 39° to 40° F., and the amount of mechanical work required to produce a unit of heat is 778 foot pounds. Therefore the mechanical equivalent of heat is the energy required to raise 778 pounds one foot high, or 77.8 pounds 10 feet high, or 1 pound 778 feet high. Or again, suppose a one-pound weight falls through a space of 778 feet or a weight of 778 pounds falls one foot, enough mechanical energy would thus be developed to raise a pound of water one degree in temperature, provided all the energy so developed could be utilized in churning or stirring the water.

Vacuum Fuel Feed. See *Fuel Feed, Vacuum.*

Valves.

Sleeve Valves. During the last few years there has been placed on the market a type of engine that does not have poppett valves, but which has a type of valve known as a "Sleeve Valve." See *Engine, Sliding Sleeve Type.*

Sleeve valves are made by placing two sliding

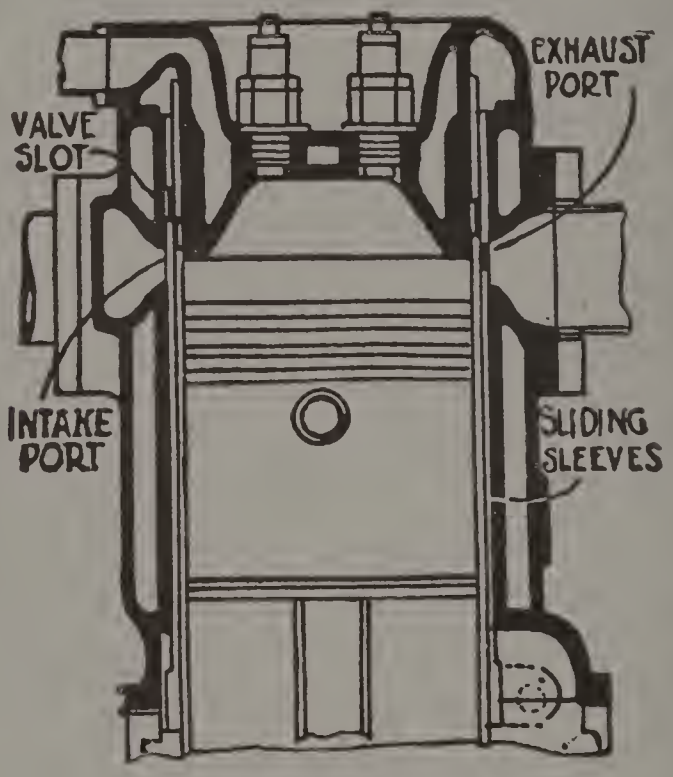


Fig. 317
Sliding Sleeve Valves

sleeves between the piston and the cylinder walls, Fig. 317. These sleeves are shaped like a section of tubing and are about an eighth of an inch thick. There are holes or slots cut through the sleeves near the top, that is, in the part of the sleeve nearest the cylinder head.

The holes, or "ports" as they are called, are placed so that when the sleeves are placed in a certain position the holes are opposite each other. When they are opposite each other they will let the mixture through into the cylinder or let the burned gas out into the exhaust pipe, depending on which thing it is necessary to do.

The lower ends of the sleeves connect with small connecting rods which are worked up and down by eccentrics on the shaft that takes the place of the cam shaft. These small connecting rods move the two sleeves up and down so that when the piston is ready to start down on the inlet stroke two of the openings come opposite each other, one opening in each sleeve. These two openings are brought opposite the opening that goes to the carburetor at the same time they are opposite each other so that the fresh mixture can be drawn into the cylinder.

After the piston passes bottom center the sleeves are moved so that the openings are not opposite each other or the opening to the carburetor and the fresh gas is shut off.

When the piston is most of the way down on the power stroke two ports on the other side of the sleeves, one opening in each sleeve, are brought opposite each other, and at the same time opposite a hole that opens into the exhaust pipe so that the burned gas can get out of the cylinder. After the piston finishes the down stroke, goes up on the exhaust stroke, and is just past top center, the two openings are moved so

that they close the hole into the exhaust pipe and then the inlet openings come opposite each other again.

These sleeves are adjusted to open and close at just the right time by adjusting the length of the small connecting rods.

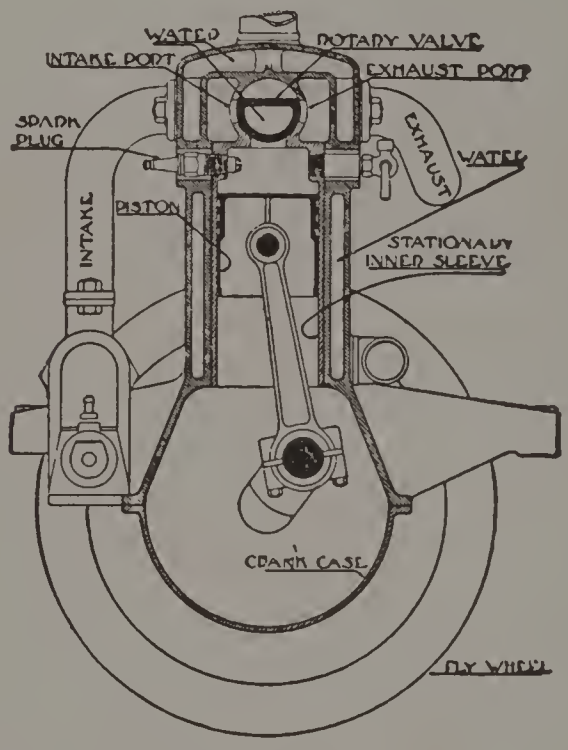


Fig. 318
Engine Having Single Rotary Valve

The opening and closing of the ports should come simultaneously with the opening and closing of the inlet and exhaust valves in a poppett valve engine.

Rotary Valves. Other engines are made without either poppet or sleeve valves but with a type of valve called a "Rotary Valve."

Rotary valves, Figs. 318 and 319, are made by having a long round shaft run along the side of the cylinders near the cylinder heads. Holes are bored through this shaft so that the holes come opposite openings into the cylinder or combustion space and at the same time open

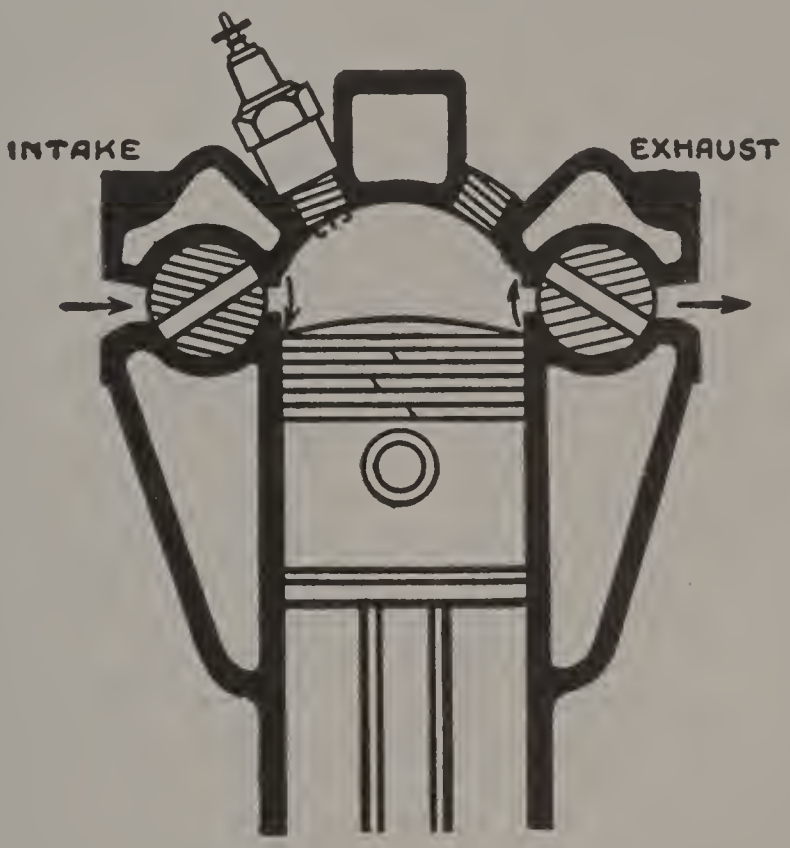


Fig. 319
Engine With Separate Rotary Valves

into the pipe leading to the carburetor or to the exhaust pipe, according to the position the piston is in and the stroke it is making.

This long shaft or valve is set in a position to open the inlet holes at the same time as the inlet valves should open in a poppet valve

motor, to close the inlet holes at the time the inlet valves should close, and to open and close the exhaust holes at the same time as the exhaust valves should open and close in a poppett valve engine.

The rotary valve is driven from the crank shaft by gears or chains so that it turns half as fast as the crank shaft, just the same as the cam shaft would turn.

Disc Valves. There are still other engines made with a type of valve known as a "Rotary Disc Valve." These valves are in the shape of a piece of round iron as large around as the top of the piston and about a quarter inch thick. They are placed on the top of the cylinder and fastened to gears so that they rotate or turn around.

Holes are cut through the disc so that they come opposite holes cut through the cylinder head. Some of these holes connect with the pipe that goes to the carburetor and others connect with the exhaust pipe.

The discs are made to turn so that the inlet holes and exhaust holes are opened and closed at the same times as the inlet and exhaust valves are opened and closed on a poppett valve motor.

Pitted Valves. A valve in a pitted condition causes bad compression, and the exhaust-valve should be ground occasionally. After grinding the exhaust-valve be sure that there is ample clearance between the valve and the

lifter. It should have not less than one hundredth of an inch, otherwise when the valve becomes hot it will not seat properly, poor compression being the result. In grinding a valve there is no occasion to use force, and the grinding should be done lightly, the valve being lifted from time to time so that any foreign substance in the emery will not cut a ridge in the seat, or the valve itself. After grinding the valve always wash out the valve seat with a little kerosene, and be careful that none of the emery is allowed to get into the motor cylinder.

Valves which need reseating should first be ground in place with fine emery and oil, then finished with tripoli and water.

A good mixture for grinding valves may be made by using fine emery and cylinder oil mixed in the form of a paste convenient to work with.

Exhaust-Valve Sticking. Sometimes a motor may suddenly stop from the failure of the exhaust-valve to seat properly. This may be due to the warping of the valve, through the motor having run dry and become hot, or it may be from the failure of the valve spring, or the sticking of the valve-stem in its guides. The valve should be removed, and the stem cleaned and scraped, or straightened if it requires it, until it moves freely in the guide, and the spring is given its full tension. If the valve still leaks so that the motor will not start or

develop sufficient power, the valve will have to be ground into its seat.

Valve Grinding. To grind a valve proceed as follows: First loosen the lower end of the valve spring from the lower end of the valve. This may be held by a number of different devices such as washers with pins under them, or grooves cut in the valve steam into which a washer slips. To loosen the spring it must first be pried up from the bottom, that is, so the end of the spring is held away from the end of the stem. This may be done by a special valve spring lifter or the repairman can make a forked lever so that the prongs fit on each side of the stem and lift the spring by resting the lever on some solid piece. Sometimes the spring can be lifted by taking a common screwdriver and using it to pry with. Before the spring can be raised, however, the cap that covers the head of the valve must be removed or at any rate the head must be reached. Now take a screwdriver or hammer handle or a piece of wood and wedge it into the valve pocket so that the head of the valve cannot lift. If this was not done the whole valve would lift when you pried up on the spring.

After the spring is pried up out of the way remove whatever locking device was holding it and then the valve may be taken out of the hole above the valve head by letting the stem slip through the spring and locking parts. You can now examine the face and seat and you will

probably find them pitted. Also examine the stem, and if it is dirty or covered with soot (called carbon in the automobile business), it should be scraped clean with a knife blade or some sharp instrument. There must be no ridges on the valve stem that might keep it from seating the valve properly.

A valve stem must never be oiled or greased under any conditions. They are designed to work dry.

The valve is ground by placing some cutting material between the seat and face and rubbing them together. Valve grinding material may be made by taking emery powder of a fine grade and mixing it with enough engine lubricating oil to make a rather thin paste, or it may be made by mixing the emery with lubricating oil and kerosene. It may also be made by mixing powdered glass with a thin oil into a paste, this being used mostly for finishing the operation. If a very fine fit is desired a paste can be made with crocus powder and oil. A rather coarse paste is used at first if the surfaces are badly pitted and the finer, smoother pastes are used for finishing.

After making the paste take a cloth (not a piece of waste), tie a string to it and stuff the cloth into the opening from the valve pocket to the combustion space. This is to keep the grinding material out of the cylinder, where it would do great harm.

On the top of the valve head you will find a

slot for a screwdriver or else some holes that take the end of a special fork-shaped tool. These let you turn the valve face on the seat, and you will need a tool that fits the particular valve head you wish to work with. You will also need a small can of gasoline or kerosene handy so that the grinding compound may be washed from the valve and seat.

The operation of valve grinding consists of placing a small amount of the grinding compound evenly on the face but not very thick. What you can easily pick up on the tip of a pocket knife blade is plenty at one time. The valve is now placed in the cylinder or part that it came out of so that the face rests on the seat. Now take the tool that turns the valve and turn the valve about half way around and then back again. Do this several times. Do not use much pressure as the pressure forces the grinding compound from between the face and seat and makes the work slower.

After making several half turns the valve head must be raised and turned to a new position while it is not touching the seat, and then the operation is repeated. If you do not raise the valve from the seat every few half turns you will make ridges on the face and spoil the job. Also, if you turn the valve round and round without reversing the motion and raising it you will spoil the work. In order to raise the valve from the seat every once in a while you can take a light spring that fits around the stem and

place it on the valve stem just under the head. This spring should rest on the metal of the cylinder at its lower end and hold the valve about a half inch off the seat. When you press on the valve grinding tool the valve will be pressed down onto the seat, but when you release the pressure it will raise again and you can turn to a new position without pushing up on the stem from below.

The valve must be ground for a few minutes and then washed off and carefully examined. When the face and seat are a clean even light gray all around and have no marks or pits or rings at any point the job is finished and the valve should be gas tight.

The next thing to do is to test the valve for tightness. This can be done by placing pencil marks at short distances all around the face and then pressing the valve down and turning it once around. If the marks are all off the face it will be tight. You can also pour gasoline or kerosene on top of the valve and watch for it to run down the stem. If it does not leak through it is tight.

Now wash every trace of grinding material from the valve and the seat and valve pocket and replace the valve with the spring and the valve cap.

Valve Clearance. A large number of motors, especially old ones, are unnecessarily noisy because of superfluous clearance between the valve lifters and the valves, and a great part of the noise may be eliminated simply by the expenditure of a little time and care in reducing this clearance to the minimum. Every valve cam, no matter what its shape otherwise may be, is tangential at the first and last portions of the valve's movement. The sooner the valve takes hold of the cam on the lift, and the later it lets go on the descent, the slower will be the

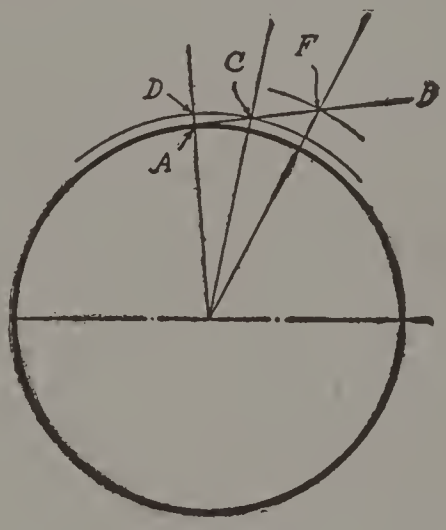


Fig. 320

movement of the valve at these instants, and the less will be the shock both of the lifter on striking the valve stem, and of the valve head on meeting its seat. Fig. 320 shows this clearly. The tangent line A B starts at A, and during the arc D C the rise of the cam amounts only to a minute distance A D.

The objection to an excessive clearance is not

simply the vertical hammering, but the sidewise pressure imposed on the valve-lifters by the cams, particularly at the instant of opening the exhaust-valves. If it were possible to operate the valves with no clearance whatever, and if there were no lost motion, and if the whole mechanism were ideally rigid, the line of pressure of the cam at the instant could be said to

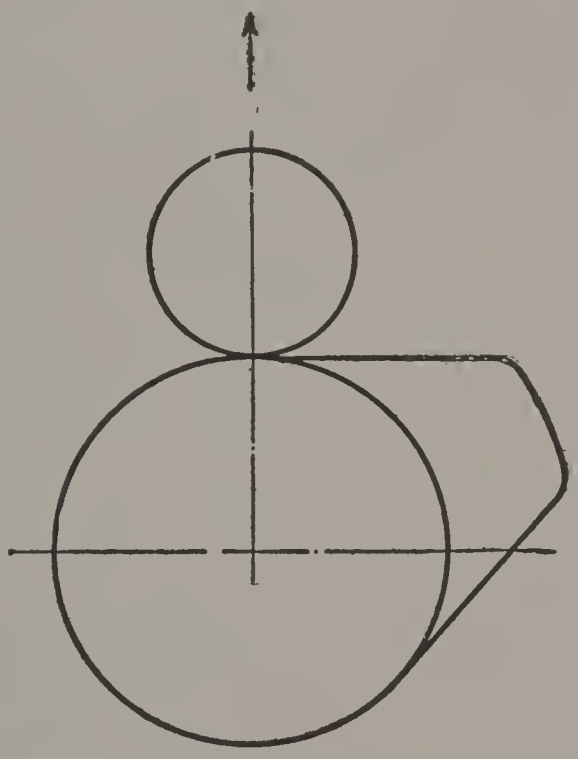


Fig. 321

be vertical, and there would be no side thrust till the valve was off its seat and the pressure of the gases on the valve was partly equalized. As the matter actually stands, however, there is a side thrust which is considerably increased by unnecessary clearance, as comparison of Figs. 321 and 322 clearly shows. In Fig. 321 there is no clearance, and the tangent to

the line of contact is horizontal. In Fig. 322 there is a clearance, AB. The thrust acts at right angles to the tangent along the line C D, and if C E represents by its length the force required to overcome the pressure on the valve and the force of the spring, there is a horizontal thrust equal to D E. It goes without saying

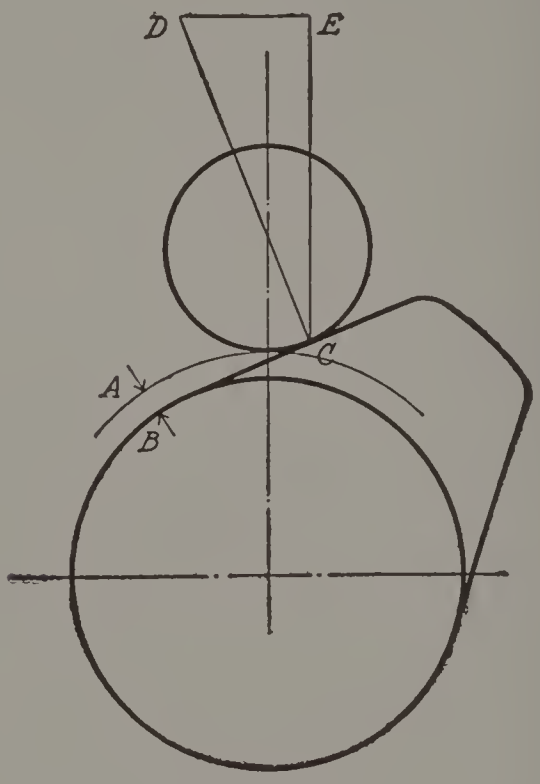


Fig. 322

that valve-lifters thus adjusted will wear loose in the guides faster than they should. As the gas pressure on the valve head may amount to 30 or 40 pounds per square inch the instant before the valve is open, there is an evident tendency to wear a hollow in the cam at the precise point where it starts the exhaust valve from its seat. Evidently, moreover, the smaller the

clearance, the greater will be the leverage of the cam, and the smaller will be its wearing tendency.

The precise amount of minimum clearance is hard to state arbitrarily. The thickness of a business card or about 10-1,000th of an inch is ample allowance for the expansion of valve stems for the average length.

Valves—Lead of. The higher the speed of the motor the greater the necessity for giving both the exhaust, and the inlet valves what has come to be known as a "lead," in that they open before the completion of the particular part of the cycle that they are intended to perform. It must be borne in mind that time is required to set a thing in motion and to stop it, regardless of its form or weight, and this is true of a gas, which has inertia the same as other substances. Further, an appreciable period, though very short indeed, is required for the creation of the vacuum in the cylinder. The gas does not rush into the combustion chamber the moment the inlet valve opens; the piston must have traveled downward a bit before this takes place and the column of gas then rushing in attains an increasing velocity as the piston approaches the lower center. In fact, it is at its greatest speed when the piston reaches the lower dead center so that the first part of its return travel has little or no effect on the incoming gas, which accordingly continues to pour into the cylinder, until the piston reaches a point on its upward

stroke, where its compression is sufficient to overcome the inertia of the stream of gas, and this is the point at which most designers of

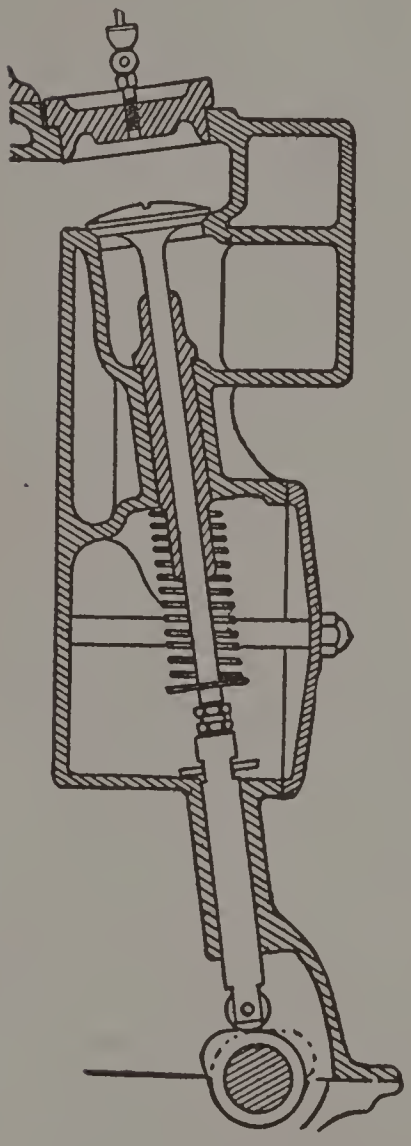


Fig. 323
Inclined Poppett Valve

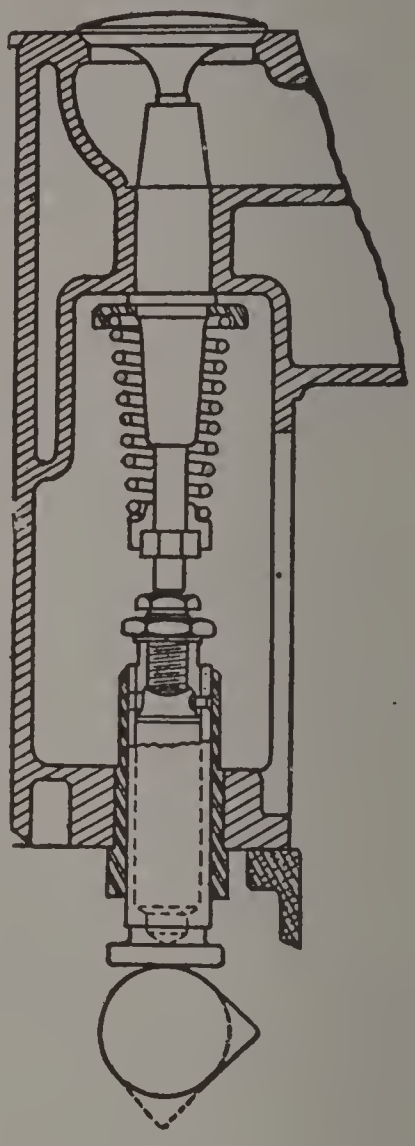


Fig. 324
Intake Valve, Poppett Type

high-speed engines set the inlet valve to close, thus permitting of the suction of the greatest possible quantity of fresh gas.

Valves, Inlet, Diameter and Lift of. For a motor of any desired bore and stroke, and speed in revolutions per minute, the following formula may be used to determine the diameter of the valve opening:

Let B be the bore of the motor cylinder in inches, and S the stroke of the piston also in inches. As R is the number of revolutions per minute and D the required diameter of the valve opening, then

$$D = \frac{B \times S \times R}{15{,}000}$$

Example: Required the diameter of the admission-valve opening for a motor of 4½-inch bore and stroke at 1,000 revolutions per minute.

Answer: As 4½ multiplied by 4½ and by 1,000 equals 20,250, then 20,250 divided by 15,000 gives 1.35 inches as the diameter of the valve opening.

In practice, a motor of 4½ inches bore and stroke has, with a mechanically operated admission-valve, an opening of 1½ inches diameter and runs up to 1,200 revolutions per minute.

The upper view in Fig. 325 shows clearly the diameter D referred to in the formula, as some persons are in the habit of referring to the outside diameter of the valve itself instead of the opening in the admission-valve seat. The center view in Figure 8 shows an admission-valve with a flat seat, which is known as a mushroom valve, on account of its shape. For this form

of valve to give a full opening the lift should be exactly one-fourth of the diameter of the valve opening: therefore if L be the required lift of the valve, and D the diameter of the valve opening, then

$$L = \frac{D}{4} = 0.25\,D$$

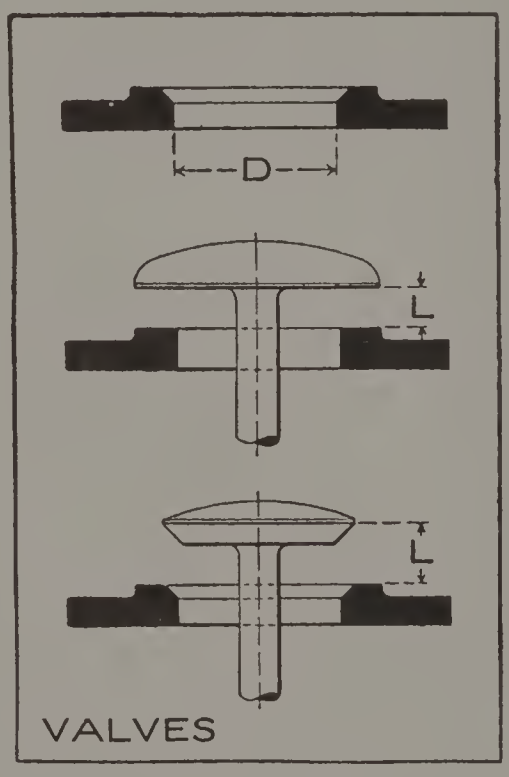


Fig. 325

The lower view in Fig. 325 shows a valve with a bevel seat, having an angle of 45 degrees, which is most commonly used. The lift of this form of valve requires to be about three-eighths of the diameter of the valve opening; that is, if L is the required lift of the valve and D the diameter of the valve opening, then

$$L = \frac{D}{2.83} = 0.35\,D$$

The bevel-seat form of valve is to be preferred to the flat-seat or mushroom type of valve, for two reasons: first, that it is more readily kept in shape by regrinding, and second, it gives a freer and more direct passage for the gases, as will be plainly seen by reference to the lower view in Figure 325.

Table 12 gives the correct diameter of valve openings for motors from 3 by 3, to 6 by 6 inches bore and stroke, with speeds from 900 to 1,800 revolutions per minute, and piston velocities of 600, 750 and 900 feet per minute, for mechanically operated admission-valves.

TABLE 12.

DIAMETER OF MECHANICALLY OPERATED ADMISSION-VALVES.

Bore of Cylinder.	Stroke of Piston.	Piston Speed in Feet per Minute					
		600		750		900	
		Revs. per Minute.	Dia. of Valve Opening.	Revs. per Minute.	Dia. of Valve Opening.	Revs. per Minute.	Dia. of Valve Opening.
3	3	1200	0.72	1500	0.90	1800	1.08
3½	3½	1030	0.84	1285	1.05	1570	1.26
4	4	900	0.96	1125	1.20	1350	1.44
4½	4½	800	1.08	1000	1.35	1200	1.62
5	5	720	1.20	900	1.50	1080	1.80
5½	5½	655	1.32	820	1.65	965	1.95
6	6	600	1.44	750	1.80	900	2.16

Atmospheric or suction operated admission-valves require to be of somewhat larger diame-

ter than mechanically operated admission-valves, for two reasons: first, that the incoming charge has to lift the valve from its seat and keep it suspended during the suction stroke of the motor piston, and secondly on account of the resistance offered by the valve spring, which tends at all times to keep the valve on its seat. For an atmospherically operated admission-valve which will insure practically a full charge in the motor cylinder the formula should be

$$D = \frac{B \times S \times R}{12{,}750}$$

The proper diameter for atmospherically operated admission-valve openings may be readily found by increasing the required diameter given in the above table for mechanically operated admission-valves, by 15 per cent.

Example: What should be the correct diameter for the atmospherically operated admission-valve of a motor of 4½ inches bore and stroke, with a piston velocity of 750 feet per minute?

Answer: Under the column headed 750 and opposite 4½ by 4½, the diameter given is 1.35. Then 15 per cent of 1.35 equals 0.20, which, added to 1.35, gives 1.55 inches as the correct diameter for the valve opening under the conditions given.

Admission-valves, Forms of. Figs. 326 and 327 are two forms of combined admission-valve

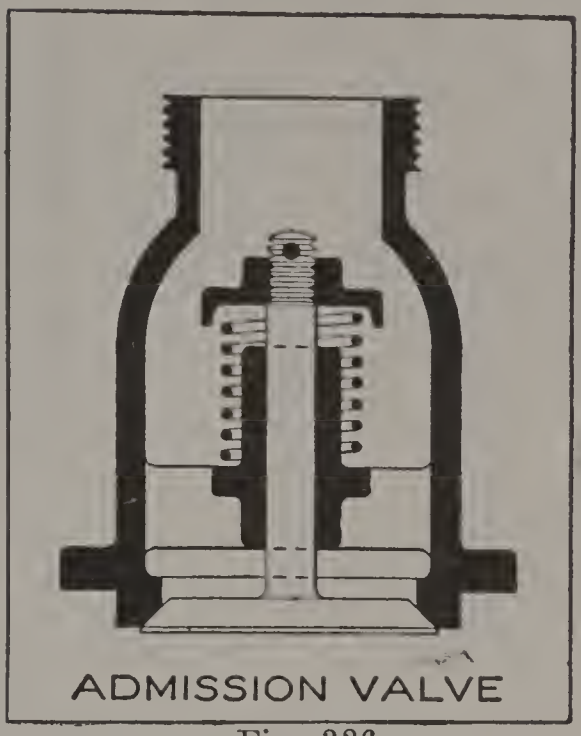


Fig. 326

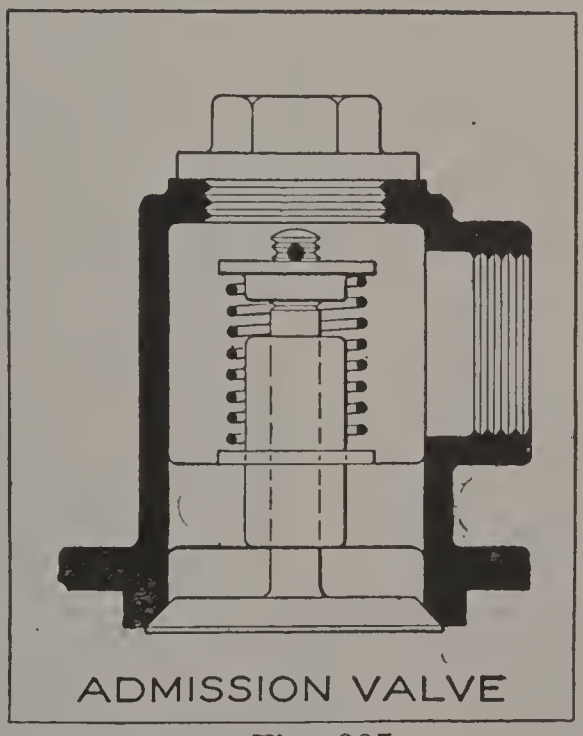


Fig. 327

and valve cage or chamber. Fig. 326 has the inlet on top and Fig. 327 on the side. Figs. 328-329 show two forms of detachable or remov-

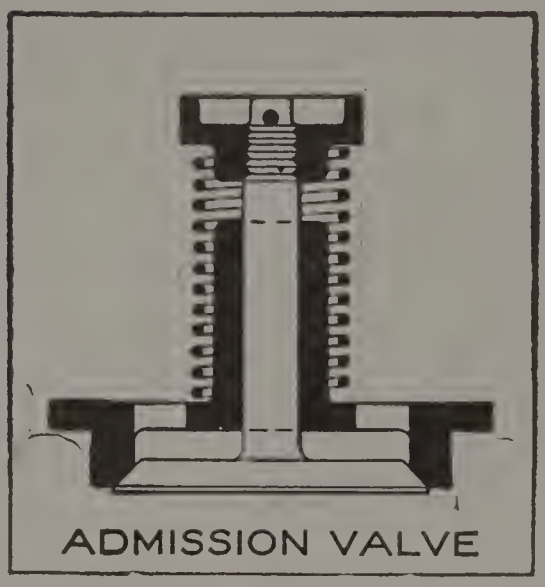


Fig. 328

able admission valves. The one shown in Fig. 329 may be removed from the motor without disconnecting the admission-pipe, as it screws

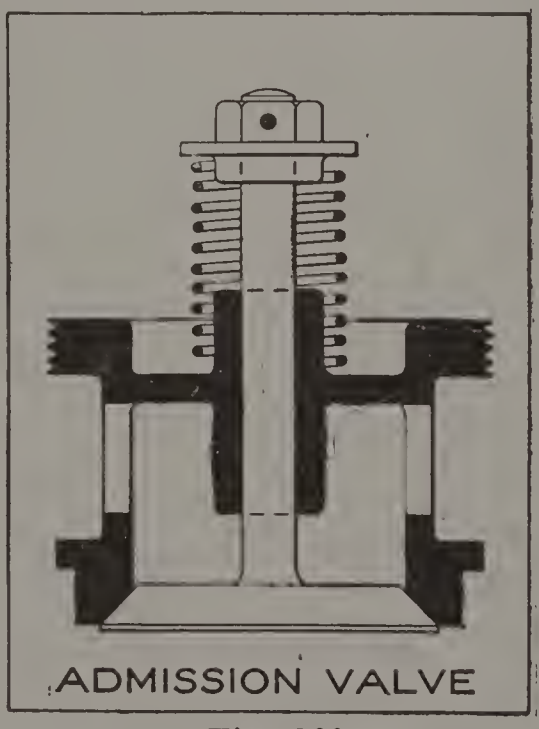


Fig. 329

into the combustion chamber, and has openings around the lower portion for the admission of the explosive charge to the valve.

Vulcanizing. See *Tire Vulcanizing.*

Watt-Hour—Definition of. A current of one ampere flowing in an electric circuit, with an electro-motive force of one volt, is equal to one volt-ampere or one watt. The voltage of a circuit, multiplied by the rate of the current flowing in amperes, gives the rate of work, or energy expended in watt-hours.

It is oftentimes found that electric lamps for automobile lighting are rated according to their consumption in watts rather than directly in amperes. The number of candlepower secured from each watt consumed will vary according to the size of the lamp in candlepower, the material of which the filament is made and the type of bulb, whether vacuum or nitrogen. A small bulb with tungsten filament will use from 1.10 to 1.25 watts per candlepower, and this is reduced until in the largest candlepower the rate is about 0.95 watts. The consumption with carbon filaments is about two and one-half times that with tungsten. Nitrogen bulbs use less current than the vacuum type.

Welding—Autogenous. This process consists of welding, or, more correctly speaking, melting together metals by means of the oxyacetylene flame, the temperature of which almost rivals that of the electric arc, being 6,300 degrees Fahrenheit. The facility with which it can be handled as compared with most other methods makes its commercial application comparatively simple. The possibilities attendant upon the use of a flame of such high tempera-

ture can be realized when it is remembered that the melting point of steel is about 2,570 degrees and that of platinum, one of the most refractory metals, is only 3,227 degrees Fahrenheit. Its chief field of usefulness is in combining such metal parts as would ordinarily be riveted, in welding small parts together, in repairing broken or defective castings and for cutting metals of any nature or size that occasions demand.

As it is possible to unite many dissimilar metals, and with a heat so localized that neighboring parts are not affected, autogenous welding has already found an extensive application in motor car repair work. Broken crankcases or other parts can be united and made practically as strong as new. The method of holding the pieces of a broken aluminum case, for example, is to clamp them into position temporarily while clay is packed around the parts and heated sufficiently to drive out the moisture, thus forming a solid support for the parts as well as a kind of mould. A series of holes are usually drilled at the crack, or the edges of the pieces are roughly beveled so, as previously explained, the metal can be built up from the bottom. In some instances lugs or peculiar shaped projections may have been completely worn off or destroyed, when it becomes necessary to build up new ones with additional metal. In repairing a cracked waterjacket, after the edges of the crack have been prepared, it is customary to use copper instead of iron wire for the filling

metal as it flows at a lower temperature and adheres very positively. In case there is danger of warping, due to local expansion, the entire cylinder is heated before operating upon it.

Wheels. The wood work of all wheels should be of selected grades of second growth hickory, or equally good growths of other hard woods. In the driving wheels the twisting moment of the motor is transmitted to the spokes of the wheels, and this torsion must be resisted by the wood at the miter, therefore, if the hub flanging is not clamped tight there is danger of the joints "working," which will soon lead to something worse. When the hub clamping bolts are tightened up they should be so pinned that they will not turn with the nuts because if the bolts do turn it will be impossible to apply sufficient pressure, and the clamping effort will be insufficient. Fig. 332 shows a hub in which the clamping bolts are prevented from turning by means of a triangular shaped extension just under the bolt heads, which engages a slot in the flange. In this hub the flange is made integral with the brake drum, which also serves for the sprocket wheel, and the torsional effort is taken by integral metal at all points, thus relieving the wood work from shock. The nuts used on the clamp bolts shown in Fig. 332 are castellated, although it is not necessary to use castellated nuts unless the flanges have to be removed, which in modern construction is

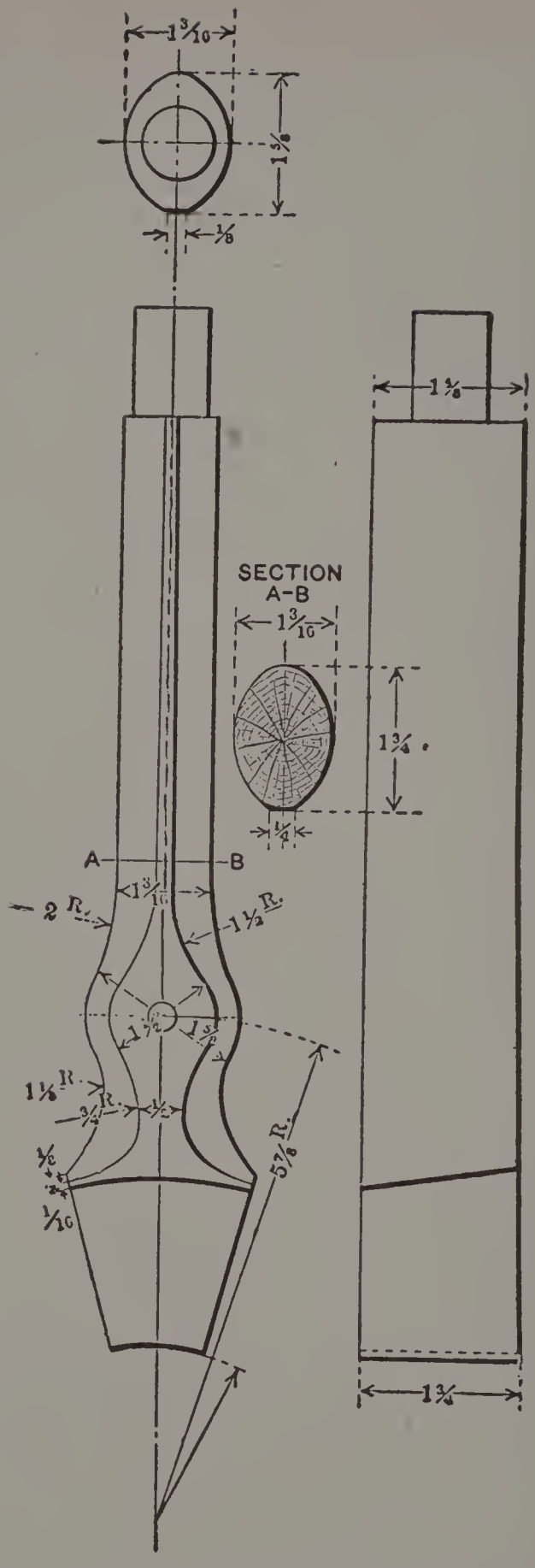


Fig. 330
Rear Wheel Spoke, Showing Proportions

the exception, rather than the rule. In ordinary practice if the wood is thoroughly seasoned, plain nuts, if screwed up tight will hold without resorting to the method so common in shop practice of riveting the ends of the bolts over the nuts. The elastic nature of the wood will serve to hold the nuts in place. Regarding spokes, a certain symmetry of contour is necessary if they are to be machine made. Fig.

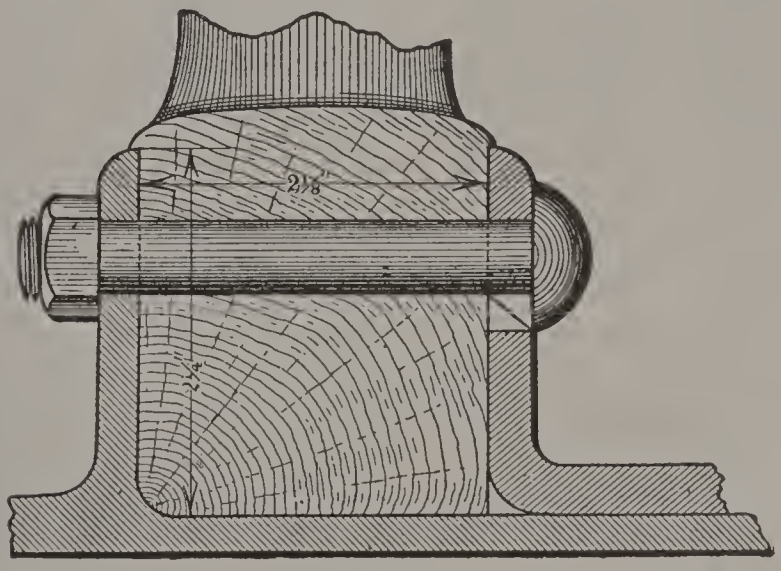


Fig. 331
Section of a Hub at the Miter Showing Depth of Flange and Method of Clamping

330 shows a spoke in which all the advantages known to wheel making are embodied, and the depth of flanging is that which experience dictates as adequate. The dimensions of the spoke are shown in detail in the cut. The brake drum is bolted to the spokes at a considerable radius, thus eliminating excess strain on the wood work.

The strength of the spoke depends in a large

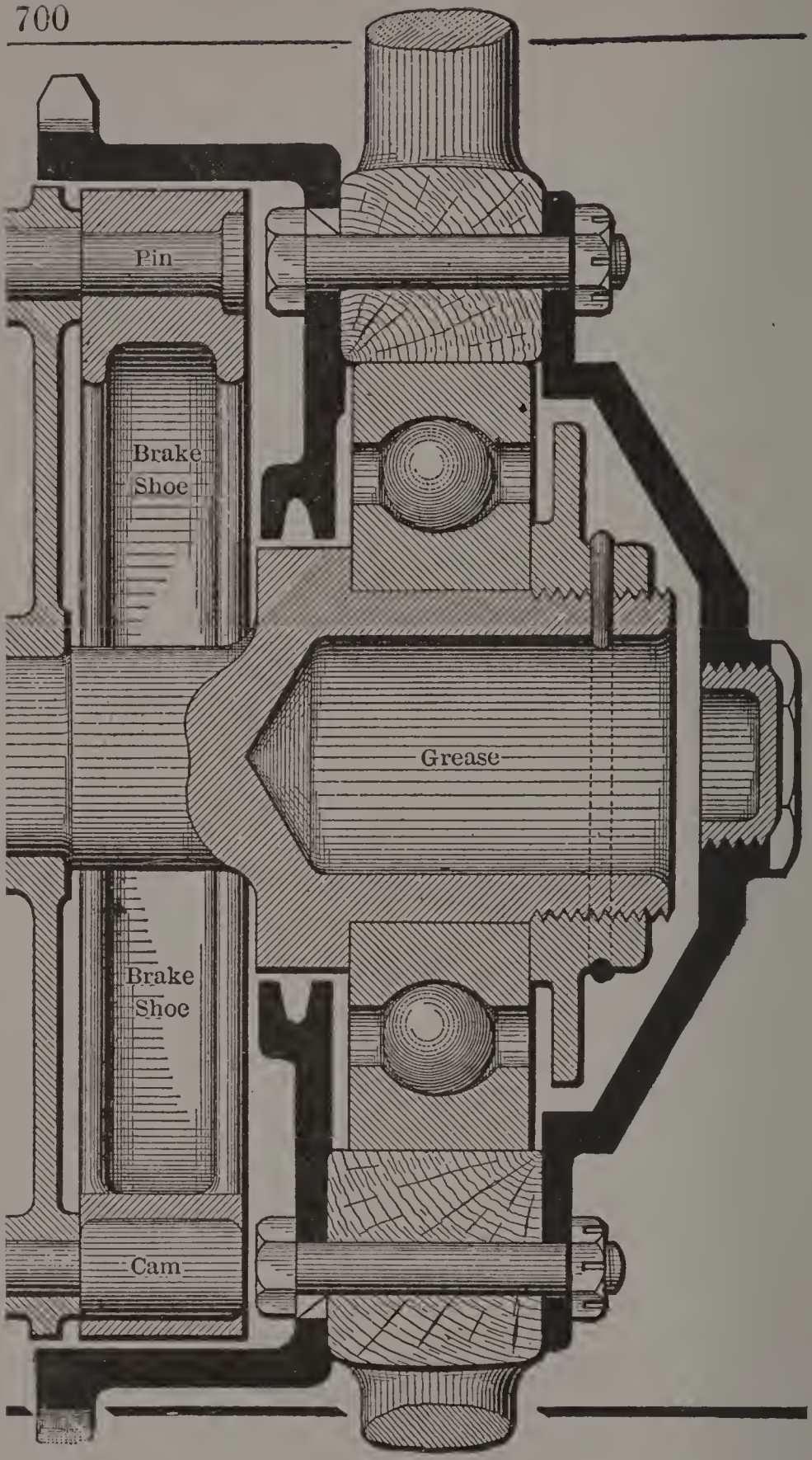


Fig. 332
Section Through Rear Wheel with Combination Brake Drum and Inner Flange

measure upon its thickness in the axle plane at the hub flange, which in Fig. 330 is 1¾ in. The second point of importance is at A, B, where the largest diameter is also 1¾ in., but in the plane of the wheel instead of the axle. At the tenon engaging the felloe, this spoke is 1⅝ in., in its major diameter, which is the plane of the

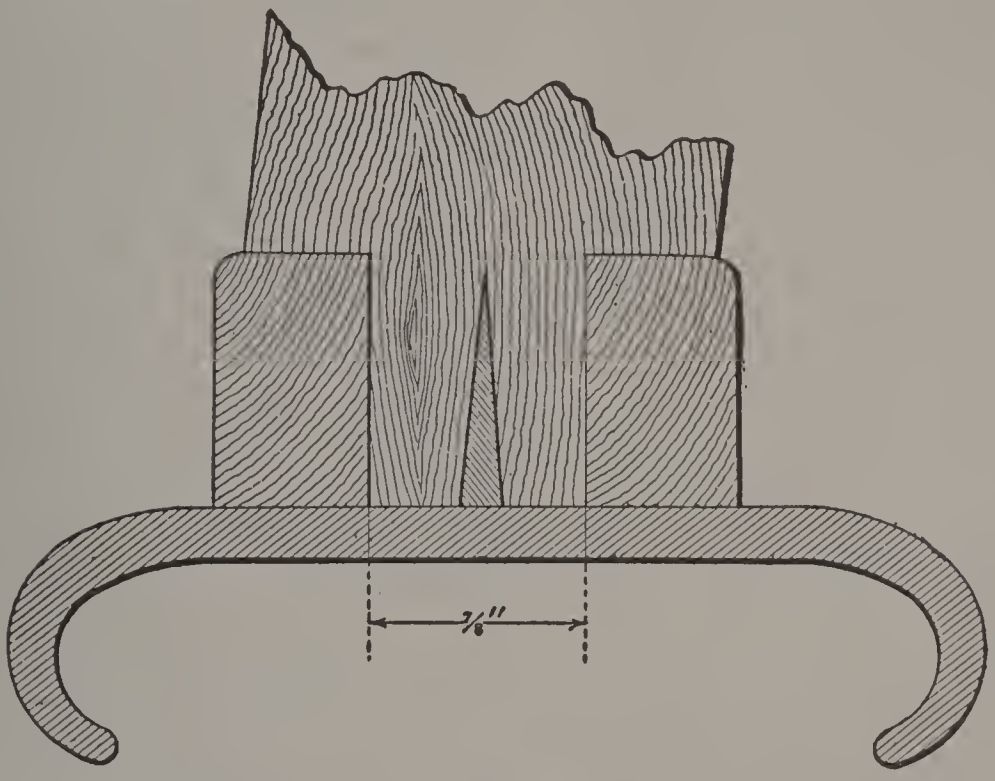


Fig. 333
Section of Felloe Depicting Tenon and Method of Wedging Which will Split the Felloe

axle, while in the plane of the wheel the minor diameter of the elliptical section is 1 3/16 in., which dimension prevails in this plane from point A, B, out to the felloe. In some types of spokes the section at the engagement of the felloe is round, and reduced gradually to the section at A, B. Fig. 331 shows a section of the

hub of another type of wheel, in which the radial depth of flanging is 2¼ in., and the axle thickness of the wood is 2⅛ in. This wheel may be used on a 60 H. P. car, and will serve as a safe example of depth of flanging, as well as a guide in fixing the shear section of the spokes for stresses induced, when cars of great power skid, provided the wheel is not dished. Fig. 333 shows the same spoke at its engagement with the felloe, indicating the manner in which the spoke is wedged into the felloe.

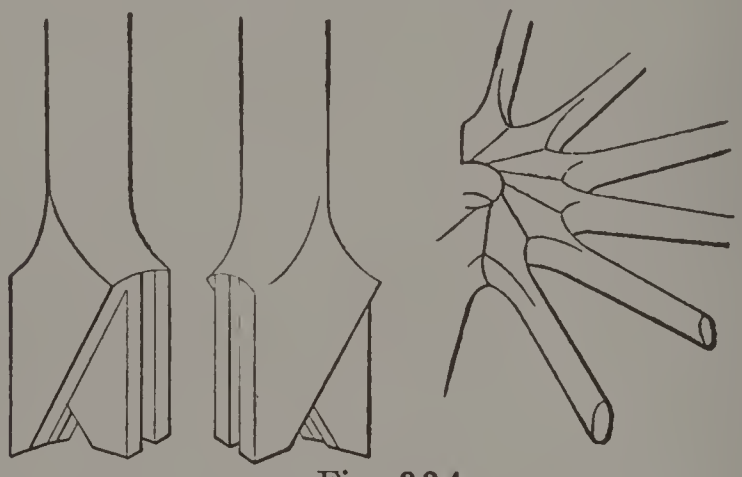


Fig. 334
Schwarz Wheel Showing Miter Joints

Figure 334 shows the Schwarz type of wheel, indicating the method of overlapping the miter, thus making it possible to true up the wood work independent of the hub. Fig. 335 shows a section of the hub, spoke and felloe of a dished wheel, and it will be seen that the felloe is not in the plane of the miter, and the dish of the wheel is outward. When a car is running at a comparatively high speed rounding a curve, the outer wheels are stressed in such a

manner that the tendency is to set a dish in them exactly opposite to the dish given by the wheel maker.

The shorter the spokes are, the greater will the dishing have to be in order to insure that the spokes will be enough longer than the radial

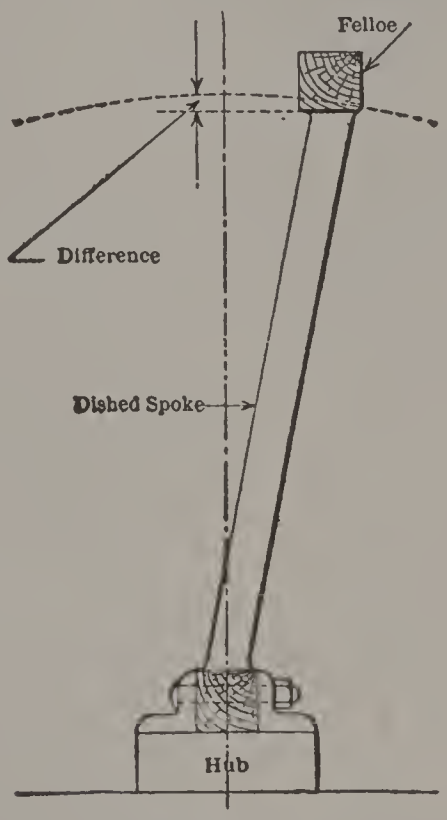


Fig. 335
Section of a Wheel Showing the Dish, Which Has Strength to Resist Skidding and Lateral Stresses

distance from the hub end of the spokes to the bearing against the felloe, to serve as members in compression, and the rim on the felloe will have to do the work. As the cut shows, the excess length of spokes marked "difference," represents the versed sine of the angle of the spokes.

Wheels, Steel. Steel is extensively used in the manufacture of wheels for automobiles. These types include steel disk wheels designed especially for trucks; wheels with cast-steel spokes, built for use on either trucks or automobiles; also wire wheels, which will be described later on.

Figure 336 shows the design and construction of a resilient spring steel wheel. It consists of a special hub which may be bored or machined to fit any standard axle, a set of single leaf springs of specially treated chrome vanadium steel, and a rim that holds the ends of the springs and also serves as carrier for the tire.

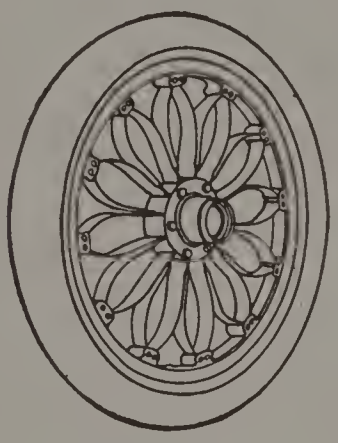


Fig. 336
Ackerman Wheel Which Has Resilient Steel Spokes

These springs or spokes are carried by a center bearing, and they carry the load under torsion at all times. In the automobile wheel there are twelve of these spokes, each leaf being made of sufficient width and heavy enough to take care of the load for which it is designed. Provision is made for a forty per cent overload in the design of the springs, which means that the steel will never be strained beyond its elastic limit. This provision against overload prevents fracture of the

spokes under load vibration or in ordinary road travel.

Wire Wheels. The development of the wire wheel has been very rapid during recent years. The invention of the wire wheel created a radical change in the method of load carrying, due to the fact that, instead of the compressive strain brought to bear upon a few spokes underneath the axle, as is the case with the ordinary type of wheel, there is a tensional stress on a large number of wire spokes, and the weight is thus held in suspension by the wire wheel with its steel rim and steel wire spokes.

Although the pneumatic tire is a great absorber of jolts, if the wheel strike an obstruction the shock of which is beyond the capacity of the tire to absorb, and if the wheel is fitted with rigid spokes, this shock is passed directly to the axle and from thence to the car springs, and unless these are equipped with efficient shock absorbers, the passengers are sure to feel the effects of rough riding. On the other hand the spokes of the wire wheel all act as a complex yet effective shock absorber, and in this way tend to reduce in a large measure the annoying effects of these vibrations. Another advantage in connection with the use of wire wheels is that the wheel itself, owing to its construction and the nature of the material, acts as an effective tire cooler, which is not the case with the wooden wheel, for the

reason that the spokes of the latter do not tend to radiate the heat generated in the tire while running, consequently this heat must radiate from the tire and rim and the process is a very slow and ineffective one. Regarding the two important features of durability and lightness of weight, experience has demonstrated that the wire wheel compares favorably with the wooden wheel. It is claimed that the lightness of the wire wheel is an important factor in reducing the tendency to gyroscopic action, which is always present in wheels running at high speeds.

The number of spokes in each wheel and method of their attachment to the hub and the rim vary according to the ideas of the designers. In some types of wire wheels the rim only is demountable, while other types have all the functions of a demountable rim and a demountable wheel. The Lindsay twin wire wheel (a semi-sectional view of which is shown in Figure 337) is a notable example of the latter type. The component parts of the Lindsay wheel are assembled into two complete self-contained sections or units, hence its name. There are eighty spokes that connect the rim parts and hub parts together. The wheel as a whole is mounted on the inner fixed hub and interlocks with it, also interlocking with the web of the brake drum. The form of structure gives two rows of spokes laced in each side of the wheel, thereby taking care of the side

thrust from either side equally. The tire rim is mounted between the two conical felloe rims of the two wheel sections and is held in place by the rim bolts, thus making it secure. Since the tire rim is secured in place between

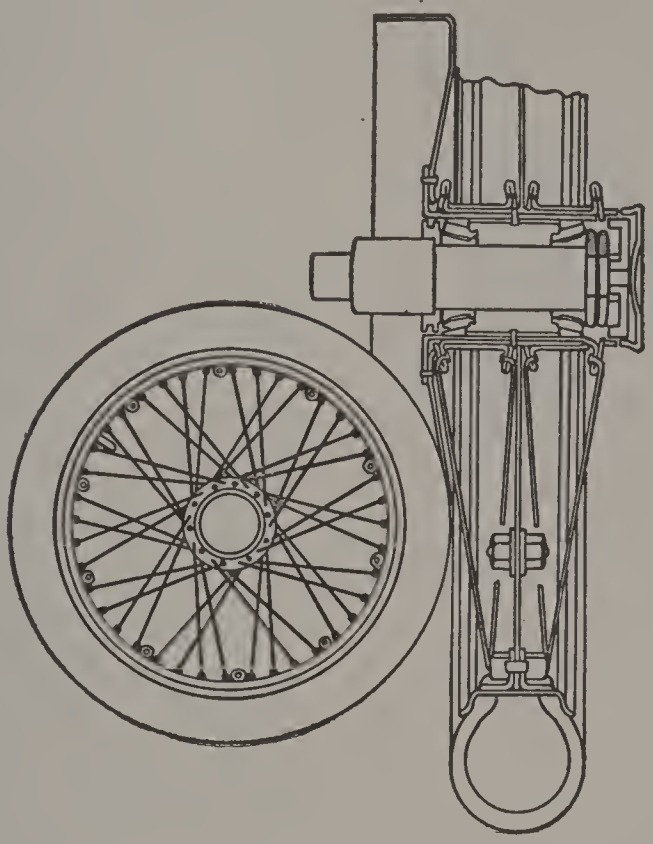


Fig. 337
Lindsay Twin Wire Wheel

the two wheel rims by means of rim bolts it is evident that both wheel and tire rims will expand and contract together. By removing the rim bolts with a wrench and taking off the hub dust cap, the outer twin wheel can be dismounted, leaving the inner wheel intact, thereby releasing the tire.

Another type of wire wheel is the Spranger,

a view of which is shown in Figure 338. In this wheel there are 48 spokes interlaced in a simple cross system and equipped with a demountable rim, which like the demountable

Fig. 338
Spranger Wire Wheel

rim on a wooden wheel, can be removed for the changing of the tire. The Spranger wheel itself is not demountable, and when installing these wheels on his car the owner obtains a complete new set of bearings, brake drums, and

hub caps. This type of wheel has recently come into extensive use on the Ford and Chevrolet cars. In the construction of the Spranger wire wheel a special type of channel is used. This channel is of structural steel, and is 1½ inches in width by ¾ inch in depth, and into it the spokes are laced. The method of locking the rim to the wheel is as follows: each rim has six steel blocks securely riveted to it, which prevent the rim from rising or losing position, while at the same time there is no wedging action.

In Figure 339 is presented a view of the Houk wire wheel, made by the Wire Wheel Corporation of America.

Each wheel contains 72 steel wire spokes, each of which, before the wheel is assembled, is subjected to a test and must withstand a strain of 3,200 pounds. The spokes are arranged in triple rows as will be seen by the illustration, the triple lacing thus providing a set of spokes to take up the strain from any direction.

One end of each wire spoke is securely riveted to the rim, while the other end is secured to the hub in its proper location also by riveting. It is claimed that the interlacing of the spokes is of such a nature that three-fourths of them are continuously in use, supporting the load by suspension. In case of tire trouble, such as a puncture or blowout, the wheel can be removed in a few minutes

by merely jacking up the car and unscrewing one nut. The wheel with the damaged tire can then be replaced by the extra wheel with a good tire.

Mention has already been made of the increased efficiency of the wire wheel as a tire

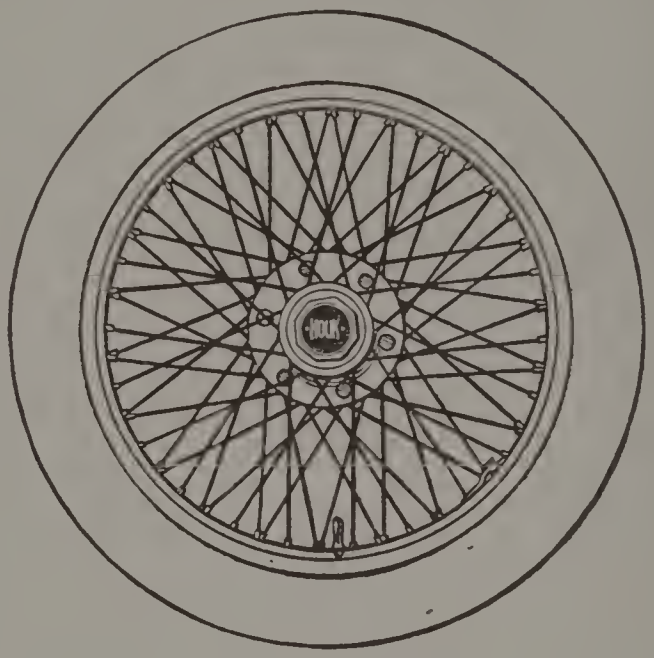


Fig. 339
Houk Wire Wheel

cooler, as compared with the wooden wheel. Another point in favor of wire wheels is the small area of spoke surface to be acted upon by the atmosphere in its resistance to the movement of the car. This resistance is always present, and the greater the area of the surface that is presented by a moving body for the atmospheric pressure to act upon, the greater will be the resistance tending to retard that movement.

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[NOTE: This index does not aim to give a complete list of subjects treated in *The Automobile Handbook.* The subjects generally are arranged in alphabetical order throughout the book. This index includes the sub-headings under the principal general headings.]

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STARTING

AND

LIGHTING SYSTEMS

(Continued)

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AUTOMOBILE STARTING AND LIGHTING

CHAPTER I

ELECTRIC LIGHTING AND ENGINE-STARTING EQUIPMENT

The fundamental principles employed in all of the various makes of automobile electrical equipment are the same regardless of the particular application chosen by the designers and builders. All systems must provide parts which accomplish certain results essential to the operation of the system as a whole.

In some cases a single part may perform two or more functions, in other cases separate parts will be provided for each function, while in still other cases some of the parts may apparently be absent. Nevertheless, every successful electrical installation must cause the same actions to take place, and parts must be provided that will bring about the effects necessary for continued operation.

It is first of all necessary to cause a flow of electric current, and this is done by the dynamo, or generator, operated by the gasoline engine. A certain amount of power is required to run the dynamo, and this power is taken through gears, chains or belts between the engine and dynamo or by mounting the dynamo on the engine crankshaft. The dynamo may be

defined as the mechanism that changes the mechanical power received from the engine into electric current.

It is evident that the engine cannot always be running when current is required, inasmuch as it is necessary to light the lamps under this condition and to start the engine from rest. It is, therefore, necessary to accumulate and store the surplus energy that is produced during the time the engine runs under its own power, and this is accomplished by the storage battery which is a vital part of every electrical equipment.

Having a source of current and a means of retaining a part of the energy until it is needed, it remains to attach the parts that consume current in lighting, starting, ignition and control of the automobile. These parts include the various lamps, an electric motor for cranking the engine, and in many cases the parts for ignition, gear shifting, carburetor heating and the many electrical accessories which are found in use.

Thus, the four essentials of the electric system are dynamo, battery, lights and starting motor. In order to allow the operator of the car to use these parts, and to cause them to perform their duties properly and without danger to themselves, certain controlling and regulating devices are necessary.

For convenience in further explanation, the electrical apparatus of the car will be divided into three principal parts (Figure 1), the charging system, the lighting system, and the starting system. The charging system will include the dynamo, the battery, and all the parts required for their operation and use. The lighting system will include the lamps and their

wiring, also the parts needed for their control. The starting system will include the starting motor, the starting switch and the necessary wiring.

In order to prevent confusion, the following usages have been adopted and will be followed throughout this work. While both words refer to the same instrument, the word "dynamo" will be used in preference to "generator" whenever the dynamo-electric machine is used to cause a flow of current. The word

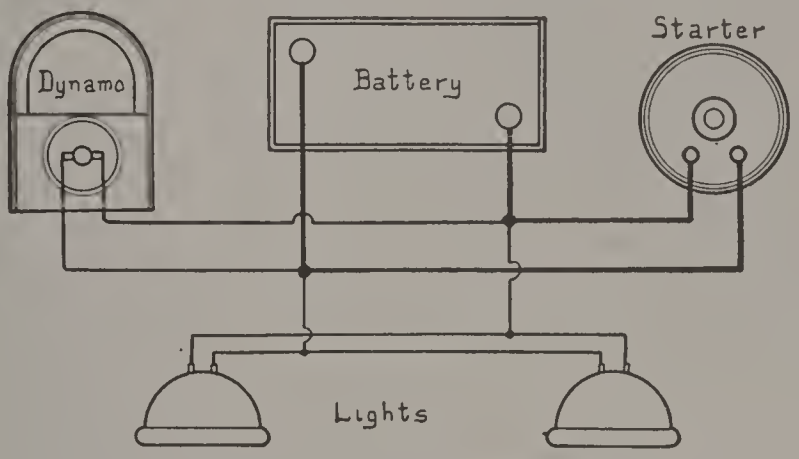


Figure 1.—Connections for Charging, Lighting and Starting Systems.

"motor" will refer to the electric starting motor and not to the automobile engine. The combination of dynamo and motor in one unit will be called a "motor-dynamo." For an explanation of the meaning of electrical words and terms used in starting and lighting, see Chapter IX.

CHARGING SYSTEM

Dynamo.—The dynamo consists of a revolving element, operating in connection with a stationary element. The rotation of one of these parts with reference to the other generates a flow of electric current in one of them, called the armature, and

the current then passes from the armature out of the dynamo to the battery and other electrical parts. The second element is called the field magnet, and provides the necessary magnetism.

The usual construction, Figure 2, makes the armature the rotating element, and the most common form of armature is built by mounting on a shaft a suffi-

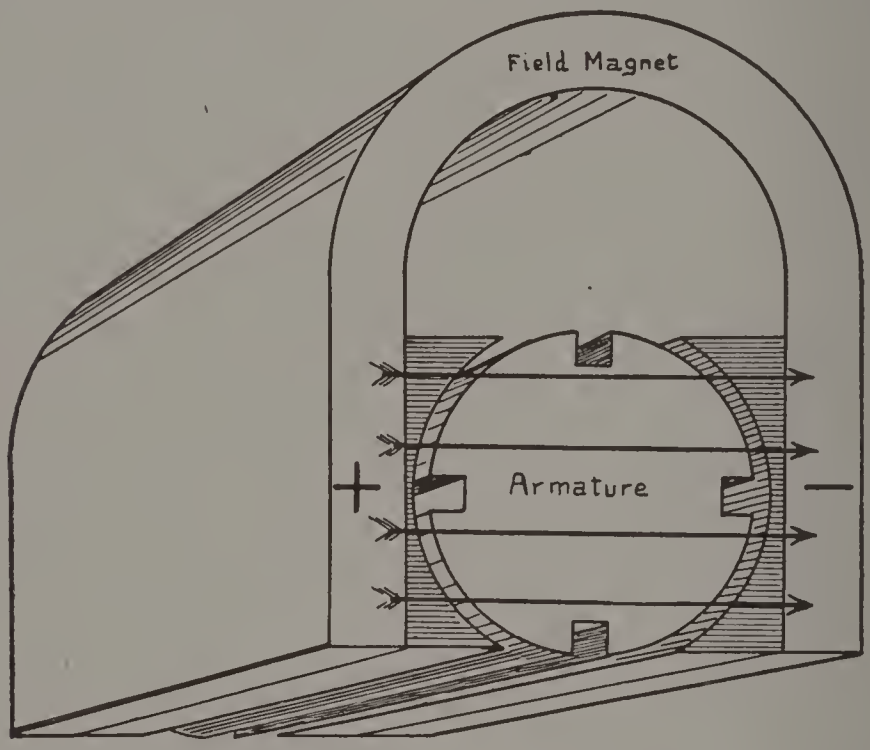


Figure 2.—Lines of Force Passing Through Dynamo Armature.

cient number of soft iron discs to make a cylinder, or else a cylindrical piece of soft iron is used in one piece. This part is called the armature core. Running lengthwise of the core are a number of grooves or slots, these slots being of sufficient width and depth to allow a quantity of insulated wire to be wound on the core and in the slots. The coils formed by this wire are called the armature windings, and it is in these windings that the current flow is first generated.

Various forms are adopted for the field magnet,

the shape depending on the size and mounting that will be required for the particular machine being designed. If a single magnet is used, that is, a magnet having but two ends, these ends are placed in such a position that they are at opposite sides of the armature core and the magnetism that passes from one end to the other must therefore pass across and through the armature core. The ends of the magnet are curved to bring them close to the armature, and the cylindrical passage between them, in which the armature rotates, is called the armature tunnel.

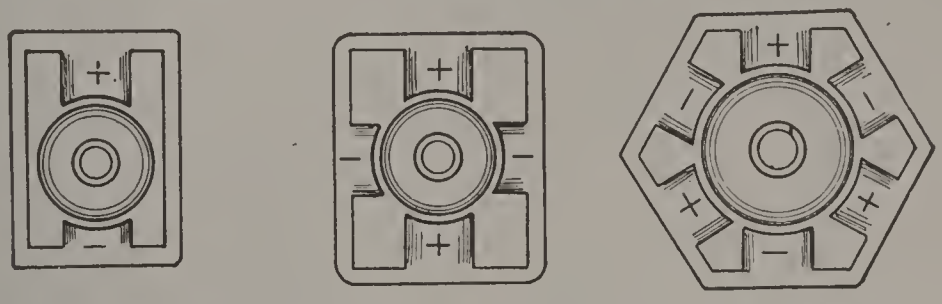


Figure 3.—Two-Pole, Four-Pole and Six-Pole Electric Machines.

Should the magnets be formed with four or six ends, as is often the case, the ends are placed so that they form pairs on opposite sides of the armature and are directly across from each other. The machine is then called a four-pole or six-pole dynamo (Figure 3), depending on whether there are four or six magnet ends placed around the armature.

The magnets that produce the field are made from soft iron, and the soft iron, called the magnet core, is surrounded with a coil of insulated wire. When a flow of current passes through this wire, the soft iron becomes a magnet, this type being known as an electro-magnet, as differing from a permanent magnet, which is made from hardened steel. The coil of wire around the magnet core is called the field winding,

and the current that passes through this winding to make the core magnetic is secured by taking a part of the current generated in the armature.

As the armature rotates between the field magnet poles, the current caused to flow through each one of the armature coils travels in one direction through the wire while the armature and coil make a half revolution, and then, on the next half revolution, the current is caused to pass in the opposite direction through the winding. A current that reverses its direction of flow in this way is called an alternating current, and is not suitable for battery charging purposes because of the fact that the reversal of flow would take out as much current as it would put into the battery.

In order to change this alternating current into a flow that always travels through a wire in one direction, the commutator is used. The current having a continuous direction of travel is called direct current, and is the only form suitable for battery charging.

The commutator consists of a number of copper bars arranged in a circle around one end of the armature shaft and fastened to the shaft so that they turn with it. These bars are separated from each other by some material that will not carry electric current; in other words, are insulated from each other. Each pair of copper bars is fastened to an armature winding coil that rests in one pair of slots, and the other bars are fastened to the other coils of wire that form the armature. This construction makes it necessary to have double the number of commutator bars that there are armature windings, each pair of bars forming the two ends of one coil on the armature.

Because of the fact that a flow of current is gen-

erated in an armature coil while it is passing across one of the magnet poles, one electrical impulse is generated in each direction by a two-pole machine, as already mentioned. One complete revolution of the armature, Figures 4 and 5, will cause both sides of the coil, which means the whole coil, to pass first across the end of one pole of the magnet, then across the end of the other pole. This action will send an impulse to the commutator bars first in one direction, then in the other.

Two brushes, made from some material that carries electricity with ease, are placed so that they rest

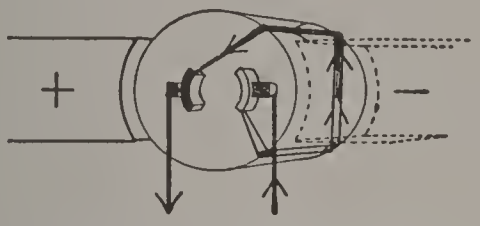


Figure 4.—Armature Coil Passing Negative Pole.

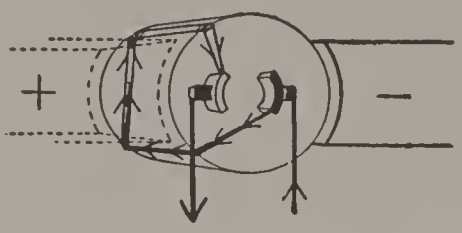


Figure 5.—Armature Coil Passing Positive Pole.

against the surface of the commutator bars and at opposite points on the commutator surface. The brushes are therefore in contact with opposite bars at the same time, and with the two ends of the armature coil. Any flow of electric current generated in the armature winding will pass into these brushes.

Now, bearing in mind the fact that the current reverses each half revolution, and also the fact that the commutator bar in contact with one brush at one position will have changed to the other brush when a half revolution has been made, it will be seen that the current will always be given to the brushes in the same direction. This is true because, while the direction of flow has reversed, the position of the commutator bars with reference to the brushes has also

reversed, and as far as the brushes are concerned, the flow continues in the same way.

Should the dynamo be a four- or six-pole unit, the reversal of current will take place four or six times in a revolution, and it is customary to provide four or six brushes, half of the total number in any case taking the current flowing in one direction, while the remaining brushes take the current flowing in the opposite direction.

From the brushes, wires and connections lead to the battery, lamps and other current-consuming devices, and in most cases to the field magnet windings also. The method of leading part of the generated current around the field magnets is one of the important considerations in dynamo design, and will be considered in the next chapter.

Current Measurement.—Electricity is not a material thing and cannot be measured according to the usual standards of weight or dimensions. It can only be measured by its effects that are produced in various ways. The two principal values of electricity that are generally useful in this work are pressure, expressed in volts, and rate of flow, expressed in amperes.

Electricity passes through conductors, such as wires and all other metallic things, because of the pressure, or voltage, and the flow sent through the conductor by this pressure is measured as amperage. The actual flow depends on the pressure being exerted and the resistance of the wire or other conductor to the passage of the current. If the voltage remains at a constant point, the flow sent through the conductor will be in proportion to the resistance; more flow passing as the resistance becomes less, and less flow

passing as the resistance increases. Should the resistance remain the same, an increase of voltage will cause an increased flow, while a decrease in voltage will allow the flow to become less.

The resistance of a conductor depends on its size or cross section, the resistance becoming less as the size increases. Resistance also depends on the length of the conductor through which the electricity must pass, the resistance increasing in direct proportion to increase in length. Other things affecting the resistance are the material of the conductor, some

Electricity	Unit of	Water
Volt	Pressure	Pounds to Square Inch
Ampere	Flow	Gallons per Minute
Watt	Power	Horsepower

Figure 6.—Electrical and Hydraulic Units Compared.

metals being much better conductors than others, and also the temperature, high temperatures generally causing the resistance to increase.

It should be clearly understood that voltage measures only the pressure and does not indicate any particular quantity or volume of electricity. Voltage corresponds to pounds to the square inch in hydraulic work and similarly indicates only the pressure that is available when a flow takes place.

On the other hand, amperage measures only the rate at which the current passes a given point, and unless the amount of time during which this flow continues is known, the amperage does not indicate the quantity of current that has passed. Amperage

may be compared to the measurement of water flow in gallons per minute, when, unless the number of minutes is known, the quantity of water cannot be calculated. (See Figure 6.)

The useful work that electric current can perform depends on the pressure, or voltage, available, and also on the rate of flow, or amperage. A current of one ampere having a pressure of ten volts will do exactly the same work that a current of ten amperes at one volt will do. Any other combination of volts and amperes which multiplied together will give ten will likewise do an equal amount of work. The work that a current will do is measured in watts, one watt being the power furnished by a flow of one ampere at a pressure of one volt. Any number of amperes multiplied by the number of volts pressure will give the number of watts. Thus, a lamp through which a current of two amperes is flowing under a pressure of six volts is consuming twelve watts in electrical power. An electric starting motor through which one hundred amperes is flowing at six volts is consuming six hundred watts in electrical power. Seven hundred and forty-six watts in electrical power is the equal of one mechanical horsepower.

Before leaving the subject of electrical measurements, it should be explained that the resistance of any material, such as a conductor, is measured in ohms, and the relation between the arbitrary units, volts, ohms and amperes, may be explained as follows:

A volt is the pressure required to force one ampere flow against a resistance of one ohm.

An ampere is the flow caused by an electrical pressure of one volt acting against a resistance of one ohm.

An ohm is the resistance that will allow a flow of one ampere to pass under a pressure of one volt.

The practical expression of "Ohm's Law," one of the most useful rules in electrical work, is as follows:

The voltage is found by multiplying the amperage by the resistance.

The amperage is found by dividing the voltage by the resistance.

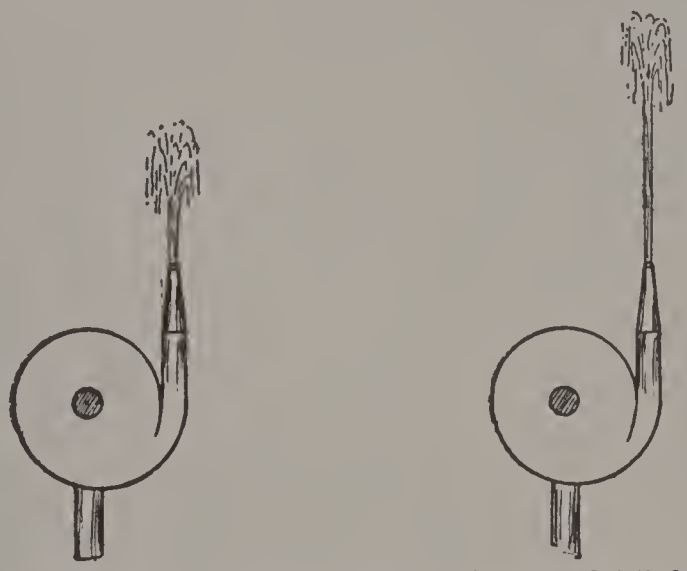


Figure 7.—Relative Pump Flow at Low and High Speed.

The resistance is found by dividing the voltage by the amperage.

It will thus be seen that, knowing any two of the above values, the third may easily be found.

Dynamo Regulation.—It is often of assistance in understanding electrical action to compare it to the action of water. The dynamo may be compared to a water pump, and the flow of electric current from the dynamo may be compared to the flow of water from a pump. In either case, the pressure increases with increase of speed and the higher pressure causes a greater flow. As the speed of a water pump increases, the water pressure in pounds to the square inch

increases, and the flow in gallons per minute then increases. (See Figure 7.) With increase of dynamo speed, the pressure, measured in volts, and the flow, measured in amperes, both increase in proportion. Just as uncontrolled increase in water pressure and flow might cause damage, so will unchecked increase in voltage and amperage result in damage to the electrical parts. Excessive amperage, or flow of current, would damage the storage battery and the dynamo itself, while an undue rise in voltage, or pressure, will damage dynamo, battery and lamps.

In order to prevent such damage, various methods have been adopted for controlling the dynamo output. A suitable operating voltage is selected when the equipment is designed, this voltage usually being six, eight, twelve or eighteen, and the design is carried out in such a way that this voltage is maintained at all times without considerable increase or decrease.

The flow allowed from the dynamo to the storage battery should be proportioned to the size of the battery, and the size of the battery is in turn suited to the current consumption of the car's equipment. Control of the dynamo output, that is, its voltage and amperage, will be designated by the word "regulation."

Cut-Out.—Following the analogy between electricity and water, compare the storage battery to a tank into which a pump, the dynamo, forces water from a lower level. It will be understood that the pressure at the pump must be higher than the pressure at the tank in order that a flow may take place from pump to tank. Similarly, the voltage of the dynamo must be greater than the voltage of the battery in order that current may flow from dynamo to battery. Just

as long as the dynamo voltage remains above that of the battery, the flow will continue and the battery will receive a charge. When, however, the dynamo voltage falls below that of the battery, as it will when the dynamo is idle or running at very low speed, then the battery pressure or voltage will be greater than that of the dynamo, and if the two units remain connected through the wiring, there will be a reverse flow from battery to dynamo. This reverse flow, if allowed to continue, will rapidly withdraw the current from the battery. To prevent such a useless and damaging battery discharge, one of several methods is adopted whereby the dynamo is disconnected from the battery when the dynamo voltage is too low to cause a flow of current to the battery. One method makes use of an automatic switch that operates according to the voltage of the dynamo, this switch acting to disconnect the dynamo and battery when the dynamo voltage falls below a certain limit and to establish the connection again when the voltage rises to a point that allows of battery charging. This switch may operate electrically or by centrifugal force, either type being called a reverse current cut-out, or simply a cut-out. A large majority of all cars use the electromagnetic form.

The dynamo is not always disconnected automatically in one of the ways described, but may be disconnected by a switch operated by the person driving the car. This type of switch is interconnected with the ignition or starting switch in such a way that the dynamo and battery will be disconnected whenever the gasoline engine is idle, or running at low speeds. The dynamo speed with the engine running at the usual rate is sufficient to produce a charging voltage.

This form of switch is often called a hand-operated cut-out.

In many cases the automatic cut-out is combined, or is carried in the same case, with the device for regulating the dynamo output. In such a design the combination is called a "controller." This practice is often followed when the regulating device is a separate instrument, complete in itself, but apart from the dynamo. Many systems are designed in such

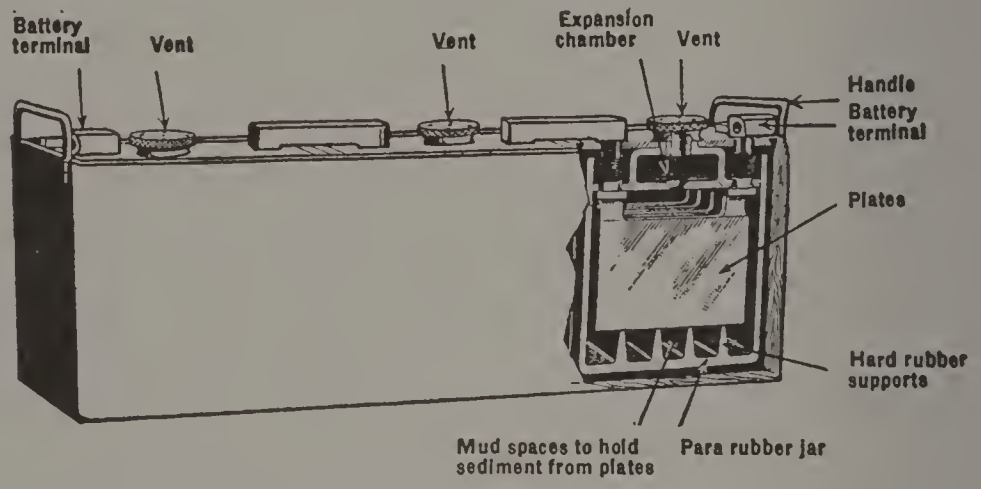


Figure 8.—Section Showing Parts of Storage Battery.

a way that regulation of output is accomplished within the dynamo and by parts of the dynamo. This internal method is called "inherent regulation."

Various locations are used for the controller or the separate cut-out. These units may be carried inside of the dynamo case or mounted on the outside of the case. They may be on the engine side or the driver's side of the dashboard. They may be placed under the driver's seat or, in some cases, under the floor boards. Other designs locate these units with the starting switch, lighting switch or other instruments.

Battery.—Although the battery, Figure 8, has been classed as a part of the charging system, it also forms an essential part of both lighting and starting systems because of the fact that it furnishes the current with which these parts operate. Being a part of each of the three principal divisions makes the storage battery the center of the whole electrical equipment and of the greatest importance.

With the exception of the battery, all units of the starting and lighting equipment operate mechanically or electrically. The battery is electro-chemical in action, and does not store electricity in the form of current. Electric current generated by the dynamo flows through the battery and in doing so causes certain chemical changes to take place in the elements of which the battery is composed. This action is known as "charging," and after the battery has been charged, the chemical composition of the elements differs from what it originally was.

After the battery has been charged, it is capable of causing a flow of current through conductors attached to it. In causing this flow the battery elements again go through a chemical change. When the action within the battery has progressed to a point at which the elements have returned to their discharged condition, the battery can cause no further flow of current. A new flow sent through the battery by the dynamo will restore the battery elements to their charged state, and connecting the outside circuits to the battery will allow the discharge which ends with a return to the chemical condition called "discharged."

This fundamental difference between the battery, which is a chemical unit, and all others, which are

electrical or mechanical, causes a large part of the trouble that results from lack of care on the part of the user.

Indicating Devices.—It is desirable for many reasons to know whether or not the battery is being charged, and also to know the rate of charge or discharge at any time. It is not possible to measure directly the amount of current flow that a battery is capable of delivering, starting with a given time; that is to say, the "charge" remaining in the battery cannot be measured. It is, however, possible to make tests which will give a close approximation of the condition of charge by testing the liquid contained in the battery. A less reliable indication is the voltage of the battery while undergoing charge. The voltage rises and falls with increase or decrease of current flow that may still be secured from the battery, and this voltage may be measured by an instrument called a voltmeter when electrically connected to the battery.

Four methods are in use which show directly when current is being sent from the dynamo to the battery or lamps. The most satisfactory method, from the standpoint of accurate information on the exact conditions obtaining at any given time, is by the use of an ammeter. This instrument, placed in the electrical circuit, shows the direction of flow and also the amperage passing. It may be so placed that the flow either into or out of the battery is indicated at the time of reading.

Other instruments, called "indicators," are used for purposes similar to those of the ammeter, the indicator showing whether the battery is being charged, discharged or held without flow either way.

The exact flow in amperes is not measured by an indicator.

A third method consists of employing a visible marker or target attached to the automatic cut-out switch, or to an electromagnet in the charging circuit, the target being fitted in such a way that the driver can tell whether or not the dynamo is delivering a flow of current. Such a target does not indicate whether the current flow is passing into the battery or to the lamps, and this method is therefore of value only for checking the dynamo action.

A fourth method makes use of a lamp called a "pilot lamp," this lamp lighting whenever the dynamo is connected to the charging circuit by the cut-out, and remaining dark whenever the cut-out is open and the dynamo disconnected from the circuits. The pilot performs the same function as the target mentioned in the preceding paragraph.

LIGHTING SYSTEM

Lamp Bulbs.—The incandescent lamps used in automobile lighting are formed by inserting a strand or filament of tungsten or carbon in a glass bulb from which all but a small percentage of the air has been exhausted. Another type of bulb replaces the air with nitrogen gas, this form of bulb giving a slightly greater volume of light for the current consumed than the vacuum type.

All bulbs are rated according to the voltage with which they are designed to operate and by the number of amperes or watts used when the proper voltage is present. Rating is also given in the candlepower developed when the bulb is consuming the rated amperage at the normal voltage.

The candlepowers in use vary from one to forty, and the voltages from three and one-half to twenty-one, according to the equipment of the car. The candlepower and voltage do not necessarily bear a definite relation to the size of the glass bulb enclosing the filament. Various standard sizes of bulb are in use, and with a lamp case and reflector designed or focused for a certain size, the use of this size should

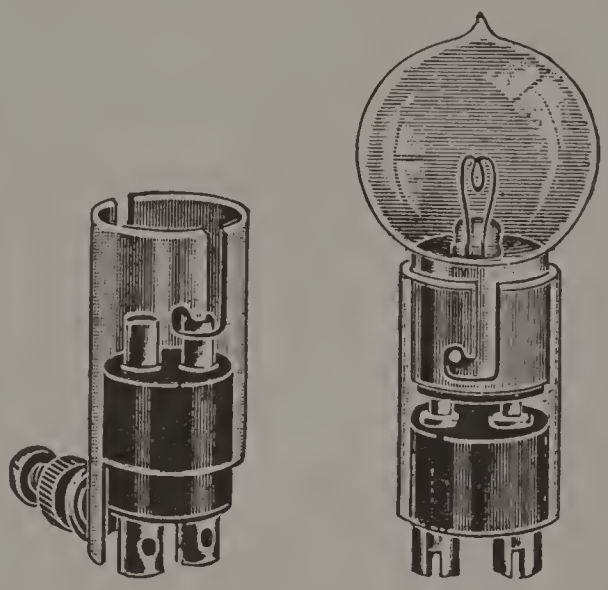


Figure 9.—Bayonet or "Ediswan" Lamp Base Construction.

be adhered to unless the focusing arrangements allow of a proper setting for a different bulb.

Three forms of bulb base and socket are in use. The type most commonly found is the "Ediswan" or "bayonet" type (Figure 9). This base is cylindrical in form and has two small pins attached to opposite sides of the round portion of the base. The bulb fits loosely into a hollow cylindrical socket, and the pins on the base slide down into lengthwise slots cut in the sides of the socket. At the bottom of the socket these slots turn at right angles and extend for a short distance around the socket, ending in a notch

designed to catch the pins on the base. Springs placed in the bottom of the socket hold the pins on the base tight in the notches. Current is carried from the socket into the bulb through contacts formed by springs or plungers. These plungers are depressed when the bulb is put into the socket and form the conductors in most cases.

In the "double contact" type of Ediswan base and socket two plungers are provided which make contact with two metallic points on the bottom of the base. One contact carries one side of the electric circuit, while the remaining contact carries the other side. The "single contact" base has but one plunger and but one point on the bottom of the base. This contact carries one side of the circuit, while the other side of the circuit is carried through the metal that forms the socket cylinder and the housing for the bulb base.

A third type, of the screw form, is seldom met with except in interior body wiring. The large size of screw base is called "candelabra," while a smaller size is called "miniature."

Wiring and Switches.—In making the necessary connections on the car, the dynamo is connected to the battery for charging purposes. All of the remaining principal divisions are also connected to the battery so that they may secure their supply of current. This means that all of the current-consuming units are connected to the dynamo and battery, the interconnection being made at the battery terminals or battery wires. Current from the dynamo may therefore pass into the battery or may go to the lamps; the flow being into the battery with all lamps off or with such a number of lamps lighted that do not require all of the current being generated by the

dynamo. If sufficient lamps are lighted to take all of the current generated by the dynamo, none will be left to pass into the battery. If so many lamps are lighted that they take more current than the dynamo generates, the battery will be drawn upon for the balance required. If the lamps are lighted with the

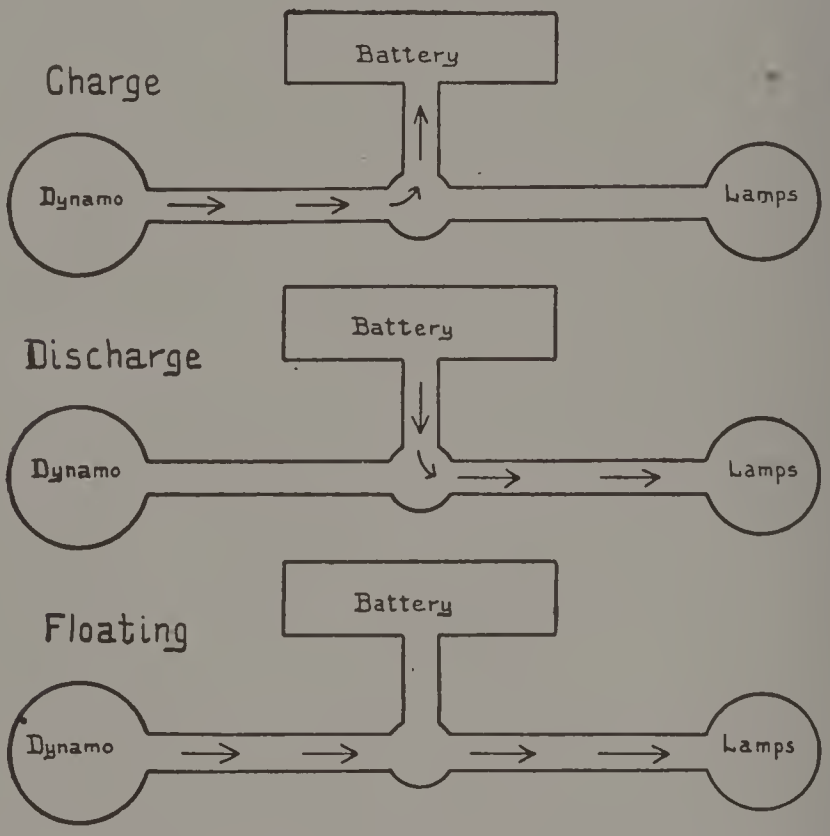


Figure 10.—Current Flow Between Battery, Dynamo and Lamps. Top: Dynamo Running, Lamps Off. Center: Dynamo Idle, Lamps On. Bottom: Dynamo Running, Lamps On.

dynamo idle, all of the current required will be taken from the battery. (See Figure 10.)

Three principal methods of lamp wiring are in use; the one-wire or ground-return method, the two-wire method, and the three-wire method.

The two-wire was used first. By this method each side of each lamp is connected directly to the battery through conductors to form a complete circuit. That

is, one side of the lamp is connected to the positive side of the battery while the remaining side of the lamp is connected to the negative side of the battery, both sides of the circuits being completed through copper wire and the necessary switches and fittings.

The one-wire method is a more recent development, but has gained rapidly in number of users since its first introduction. This method utilizes the frame and other metal parts of the car to complete one side of the circuit, this being possible because of the fact that all metals are excellent conductors. Each wire and each circuit that is connected to the frame or metal parts is said to be "grounded," and the metal parts are referred to as "ground."

The circuits for a one-wire, or ground-return, system are completed as follows: From one side of the battery, either the positive or negative terminal, a connection is made to the frame of the car, thus grounding one side of all circuits. From the remaining battery terminal wires are run to the lighting switches, to the dynamo and to the other electrical units that must have connection with the battery. These wires from the ungrounded side of the battery are led to one side of each of the lamps and other units, and the remaining side of each of these units is then connected to the frame of the car or to other metal parts in contact with the frame. These grounding connections from the electrical units often require that short lengths of wire be used, but the length of wire used is less by a large percentage than the length required with the two-wire system.

Each system of wiring has certain advantages of its own, also disadvantages. Each system has its advocates, and the arguments put forth are many for

each side of the question. The principal advantage claimed for the single-wire system is the comparative ease of insulating the parts. The size of all parts is necessarily small, and it is apparent that when the whole available space can be used for insulating one conductor, the problem is simpler. The principal advantage of the two-wire system is claimed to be the comparatively less danger of short circuits because of the fact that it is necessary to break the insulation on both positive and negative sides of the circuit before an improper flow can take place from one side of the battery to the other.

The three-wire system may be an adaptation of either the one- or two-wire system. The three-wire method makes it possible to use lamps of two different voltages on the same car and from one battery. The battery is divided into two parts of such size that one part gives one voltage desired, while the whole battery, or the remaining part, gives another voltage higher than the first. One of the three wires is called the "neutral" wire, and if a connection is made between this neutral wire and one of the others, one of the voltages is secured, while a connection between the neutral wire and the third wire will give the second voltage. Another three-wire system will give the same voltage between the neutral wire and either of the others, while a higher voltage may be obtained by making a connection between the two outside wires, omitting the neutral wire altogether.

The advantage of a three-wire system is in the smaller amperage that must be carried through the wires to do an equal amount of work. It has been explained that electrical work is measured in watts and that watts are found by multiplying the voltage

by the amperage. It will be realized that with a given amount of work to be done, the wattage will remain the same, and with the higher voltage the amperage may be reduced in proportion. The size of wire required depends on the amperage to be carried and not on the voltage, therefore a reduction in amperage allows of economy in wire.

The wiring system of the car includes the units that are necessary in making secure connections of low resistance, the switches that give the driver control of the system, fuses and circuit breakers for protection against excessive flow, and the conduits and other carriers for the conductors. While some parts of the wiring may be used only for purposes of charging, of lighting or of starting, other wires may be used for two or for all of these functions.

STARTING SYSTEM

The electric starting system makes use of an electric motor that is connected to the battery through the starting wires and the starting switch. The construction of the motor is similar to that of the dynamo already described. It comprises an armature with its commutator and brushes, all mounted on a shaft; also field magnets and field windings. The difference between a dynamo and motor does not lie in their construction, but in the fact that power is converted into electric current by the dynamo, while the motor converts electric current into power.

When current is led to the motor, it magnetizes the field magnets and also magnetizes the armature. The reaction between the two magnetic fields causes the armature to revolve within the field and power to be produced.

The construction of the type of motor usually employed is somewhat simpler and more rugged than that of the dynamo, the windings being much heavier and a lesser length of wire being used in their construction. The connections and current carrying parts in the motor must be of very low resistance, which means well made. This is true because the amperage to be carried is very large and the pressure or voltage is comparatively low. A slight increase in the resistance at any joint will offer such great opposition to the low voltage that the flow will not be sufficient to handle the work properly. When it is realized that the amperage passing through an ordinary starting motor, if supplied at the voltage used in ordinary power circuits, would develop about forty-five actual horsepower, the necessity for careful handling to avoid loss will be appreciated.

The same rules apply to the starting switch and to the wiring. They must have large current carrying capacity and must be securely and carefully connected so that the heavy currents may be handled without great loss. Fortunately, these parts are simple and of comparatively large size.

Because of the similarity of construction of dynamos and motors the two units are often replaced with a single machine having but one armature and one set of field magnets. The armature may have one set of windings and one commutator on its core or may have two sets of windings and two separate commutators and sets of brushes. The fields may likewise have one set of windings or more than one set, some being used for generating purposes only while the others may come into use only when the machine is acting as a starting motor. This combination is called a "motor-

dynamo'' and, while having certain disadvantages electrically, has the undoubted advantage of mechanical simplicity and comparative ease of mounting to offset its slightly lower efficiency in the use and generation of current.

CHAPTER II

LIGHTING DYNAMOS AND STARTING MOTORS

The size and capacity of a dynamo for a certain installation depends on the number of lamps to be used and their candlepower, also on the amount of power required to start the gasoline engine. The useful work that may be accomplished with the current supplied from the dynamo depends on the voltage and amperage, that is, on the number of watts. The output of dynamos is measured in amperage and depends to a certain extent on the speed at which the armature is turning. The exact ratio of output to speed depends on the type of regulation that has been adopted for the dynamo. Some forms of regulation allow the amperage to rise rapidly to its maximum value and then to remain practically constant, without increase or decrease, at all higher speeds. Other forms of regulation provide for a gradual rise from zero to maximum and allow the amperage to increase with the speed over practically the whole range. Still other regulating methods provide for a comparatively quick rise to the maximum amperage and then cause the amperage to decrease with greater dynamo speed. In some cases the amperage delivered by the dynamo is determined by the voltage of the battery, the amperage becoming less and less as the battery voltage increases with the approach to a fully charged condition. The practice is often followed of automatically increasing the dynamo output when any or all of the

lamps are turned on, this action serving to compensate for the additional load imposed by the lamps.

It will be seen from the foregoing statements that no general conclusions can be drawn and no general rules given by which it may be determined whether or not a dynamo is giving its proper amperage. If the characteristics of the particular machine being considered are known, the work is made easy; but in the absence of this information it is generally necessary to make additional tests on other units, such as the battery. These tests will show whether the dynamo is doing its proper work provided everything else is known to be in condition for efficient use. There is but one rule that may be useful in the superficial checking of the dynamo operation; this rule being that an ammeter attached to the battery should show a slight charge with all lamps turned on and the engine running between fifteen and eighteen miles per hour car speed.

The rule as stated will almost always hold good, and if the ammeter should show a discharge under those conditions it is safe to assume that the dynamo is not giving sufficient output or else that some trouble exists between dynamo and battery that is preventing the proper charge from entering the battery. It is of course assumed that the lighting system and wiring is in good order while making the test.

An error is often made in the application of this rule, it being stated that the dynamo output at a car speed of fifteen miles per hour should be equal to the discharge from the battery with all lamps turned on. The two statements are not equivalent because of the fact that so many important systems of regulation increase the dynamo output with the lamps turned on,

but allow it to fall to a low value with the engine running and the lamps turned off.

If it is desired to test the condition of the dynamo only, the test should be made at the dynamo itself. If it is desired to test the actual charging conditions on the car, the test should be made at the battery, because it is the charge that enters the battery that is of importance. The dynamo might be doing all that could be expected of it, but the current generated would be of no use unless it was reaching the battery, lamps, etc.

In testing the output of a dynamo, an ammeter should be inserted between one of the dynamo terminals that carries charging current and a wire end removed from this same terminal. A test made between the positive and negative terminals of the dynamo would not give the same results under ordinary conditions. With a majority of the dynamos in use, a storage battery, or its equivalent in resistance, must be in the dynamo circuit while making the test, because the output of the dynamo depends on its having to make an effort to force the current through the battery. Additional information on making such tests will be given, but the foregoing precautions should always be observed and were mentioned thus early because of the misunderstanding that so often exists.

FIELDS AND FIELD WINDINGS

A large percentage of all dynamos in use at the present time use electromagnetic fields, that is, field magnets of soft iron which are magnetized by current that flows through coils of wire placed around the field magnet cores. Dynamos have been built that use

field magnets made of hardened steel, which when once magnetized will retain their magnetic properties over long periods of time in ordinary use. Others have been built with these permanent magnets in combination with electromagnets. All forms of dynamos using permanent magnets are comparatively rare and their use is decreasing.

As previously mentioned, dynamo field magnets may be built so that the armature rotates between a single pair of magnet ends or poles, or else the construction may allow for four, six, or more magnet poles. A two-pole machine may have coils of wire on each of the poles or it may be built with the coils placed on only one pole. In the latter case the unwound pole is called a consequent pole and is of opposite polarity from the wound pole; that is, if the wound pole is positive, the unwound one will be negative, and if the wound pole is negative, the unwound one will be positive. Four-pole machines generally have but two of the poles wound, these two being of the same polarity, both positive or both negative. On each side of the armature and half way between the wound poles will be two consequent or unwound poles of polarity opposite to the wound poles.

Two-pole machines have two brushes to collect the current from the armature, one positive brush and one negative brush. Four-pole and six-pole machines may have four or six brushes respectively, or may be constructed in such a way that but two brushes are required, regardless of the number of poles.

As previously mentioned, the method of connecting the field windings with the armature brushes is of great importance in design, and in fact forms the

principal difference between dynamos of different types. It will be realized from the explanation of the poles already made, that the field windings may be on one or more than one of the pole pieces, Figure 11. The number of windings, or the number of poles that are wound, does not affect the principles used in connecting the windings; the variation in the number of parts or poles simply means that the windings are divided into several parts or are all on one pole piece. This understanding will make it unnecessary to refer to the number of poles in the following explanation of the various methods of winding.

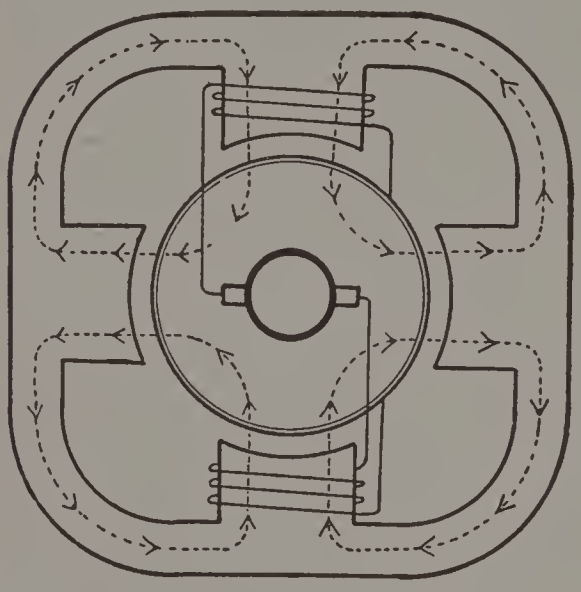


Figure 11.—Flow of Magnetism in Field of a Four-Pole Machine.

Figure 12 shows the field windings and their connections for a plain "shunt wound" dynamo. The right-hand brush is positive and the current generated in the armature passes from this brush through the heavy wires to the outside circuits, returning through the other outside wire to the left-hand negative brush. It will be noted that one end of the coil of wire around the field magnet is attached to the positive brush while the other end of this field coil is attached to the negative brush. This connection allows a part of the current from the armature to pass through the field magnet winding and thus magnetize the iron core. The direction of flow around the

magnet in this case causes the upper pole to become positive and the lower one is therefore a consequent negative pole without a winding. When two circuits, such as the field circuit and the outside circuit, are so connected to a source of current that a part of the flow passes through each circuit, the circuits are said

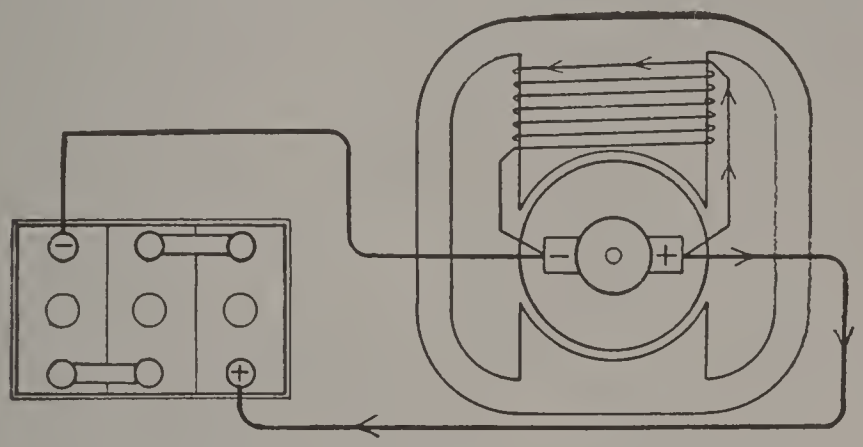


Figure 12.—Shunt Field Winding.

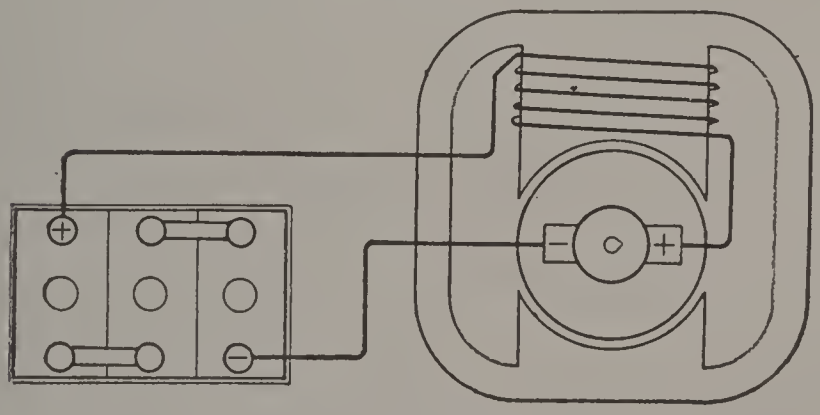


Figure 13.—Series Field Winding.

to be in shunt with each other, and either one is called a shunt with reference to the other. The field circuit in Figure 12 is therefore a shunt of the outside circuit and this dynamo is said to be shunt wound. This form of winding, with several modifications, is by far the commonest of all those in use for dynamos.

Figure 13 shows the connections that form a series winding. This method of connection is not used for

dynamos unless in combination with a shunt, but is shown because of its relation to this question. This form places the armature and the field winding in the same circuit and so that all of the current passing into or out of the armature must also pass through the field winding. Any circuit in which all of the current that passes through any one part must also pass through each and every other part is said to be a series circuit, and inasmuch as the method illustrated in Figure 13 conforms to this rule the dynamo would in this case be series wound. As stated, this form is never used for automobile lighting dynamos.

For dynamo work, the series winding is useful when combined with the shunt in either of two forms. One combination is called "compound wound," while the other is called a "reversed series" winding. In either case the series winding is used to assist in dynamo output regulation.

The direction in which the field current passes through the wire composing the field winding determines the polarity of the magnet ends. When looking at the end of an electromagnet, should the current be flowing around through the magnet winding in the direction that the hands of a clock travel, then the end being looked at is the negative pole; while, if the current travels in an anti-clockwise direction, the end being observed is positive. The magnetic strength of the field is determined by the number of turns of wire around the pole and the amperage passing through the wire. The number of turns of wire multiplied by the number of amperes flowing gives the number of "ampere-turns," and the strength of magnets is determined by the ampere-turns. It will be seen that the strength of the field in any dynamo de-

pends on the number of ampere-turns acting on the metal of the field magnets, the strength becoming greater with increase of ampere-turns. The output of the dynamo depends on the strength of the field and the speed of rotation of the armature, therefore, if the speed remains constant the voltage and amperage will depend directly on the field strength, or on the number of ampere-turns acting to produce the magnetic field.

The connections used in making a compound wound dynamo are shown in Figure 14. It will be seen that

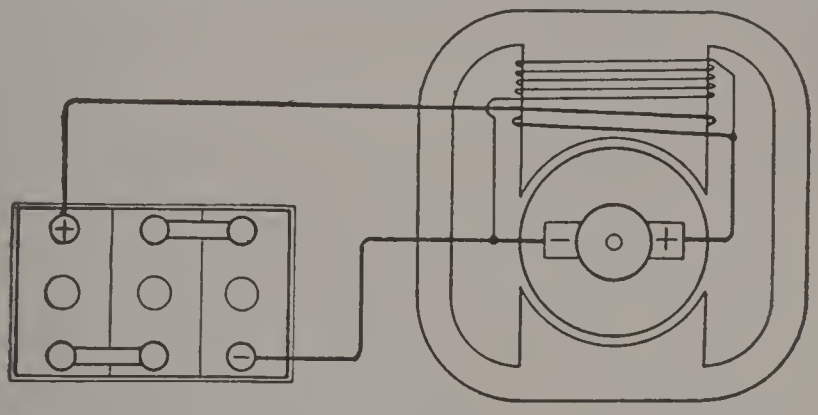


Figure 14.—Compound Field Winding.

the shunt winding is exactly similar to that shown in Figure 12, while the series field winding has been added just as it is placed on the magnet of the dynamo shown in Figure 13. It should also be noted that the flow of current through both shunt and series field coils is in the same direction, therefore they both tend to produce the same polarity in the field magnets and the series winding adds its effect to that of the shunt coil and in the same direction. The greater the flow through the series winding in the compound wound machine, the greater will the output of the dynamo become, while a decrease of flow through the series coil will lower the output.

The reversed series connection is shown in Figure 15 and it will be seen that the whole difference between this form and the compound wound machine lies in the difference in direction of the flow through the series field. In this case the shunt winding is acting at all times to make the upper pole positive and of a strength corresponding to the ampere-turns in the shunt coil. All of the current that leaves the dynamo must pass around the series winding and inasmuch as this current flows through the series coil

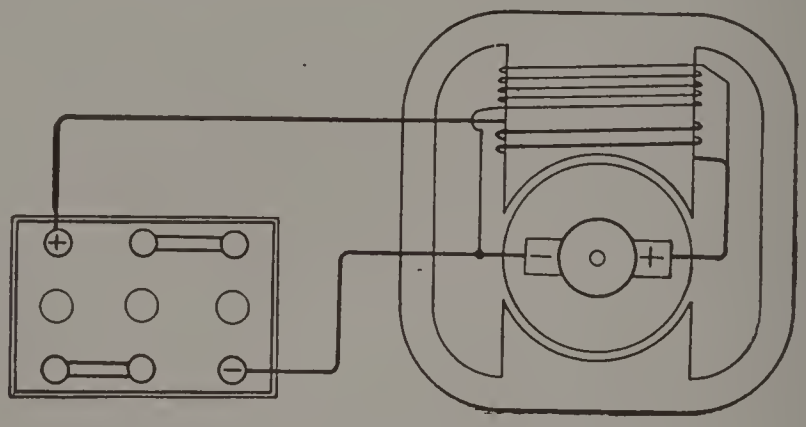


Figure 15.—Reversed Series Field Winding.

in a direction opposite to that of the shunt field current, its effect will be to oppose the shunt field and weaken the total strength of the magnet.

The normal tendency of the dynamo would be to increase the voltage and output in amperes with increase in speed, but this same increase of output passing through the reversed series winding tends to overcome part of the strength of the shunt field, weaken the magnet, and reduce the output. With this form of winding it is impossible for the dynamo output to exceed a certain value because of the opposition introduced by the series winding and dynamo regulation is thereby obtained.

One brush or one set of brushes will always be positive and the terminal connected to the positive brush side is then called the positive terminal. The remaining brush or set of brushes with the corresponding terminal or connections will then be negative. Should the flow of current around the fields be reversed in direction, the polarity of the brushes will also be reversed. With some designs of dynamo it is not desirable that such a thing should take place, while with others it is immaterial.

The initial flow around the fields is determined by the direction of the flow from the armature into the brushes and the direction of this flow from the armature is determined by the direction of magnetic flow between the field magnet poles, that is to say, the flow is determined by which pole is positive and which negative. It is assumed in this case that the direction of armature rotation remains the same at all times.

Because of the fact that the field magnets are magnetized by the flow of current around them it is often asked how the dynamo starts to generate, inasmuch as there can be no flow to start with and therefore no magnetism produced. This difficulty is taken care of by a natural characteristic of iron, this being the practical impossibility of completely demagnetizing the metal. A certain amount of magnetism, called "residual magnetism," will remain in the softest iron field cores even with the dynamo idle. When the armature starts to rotate this residual magnetism, which is the same in polarity as that obtaining when the dynamo last operated, causes a slight flow of lines of force through the armature. This allows a low voltage and small current to be generated in the armature, and this small current flowing through the field

coils strengthens them to such an extent that the current flow is further increased. The dynamo "builds up" very rapidly in this way until the full voltage and output is reached.

If the flow of current around the fields should be reversed from its usual direction, the residual magnetism remaining would be of opposite polarity from the normal, and when the dynamo was again used its terminal polarity would be changed. That is, the terminal that was positive would be negative and the terminal that was negative would be positive. Should this condition remain, the dynamo would send its current through the battery in the wrong direction with the result that the battery would suffer an extremely rapid discharge and would soon be damaged permanently.

In order to restore the field magnets to the proper polarity it is necessary that a flow of current be sent through the windings in the proper direction. Should a test at the dynamo show that the current flow remains in the wrong direction, it may be corrected as follows: First make sure that the connections between dynamo and battery are correctly placed. This means that the positive side of the battery should be connected to the dynamo terminal that should be positive, while the negative side of the battery should be connected to the dynamo terminal that should be negative. With these connections made, with a fully charged battery, and with the dynamo idle, the cut-out should be closed several times and allowed to remain closed for two or three seconds each time. Should the cut-out tend to remain closed (if of the electromagnetic type), starting the engine will allow it to open. The flow of current through the dynamo

under these conditions will restore the proper polarity at its terminals. Many types of dynamos now in use change their polarity to that of the battery the first time that the cut-out closes, and in this case it would not matter which way the connections were placed as far as the dynamo and battery were concerned.

The above remarks regarding dynamo polarity do not apply to machines having permanent magnet fields. With permanent magnets placed on the dynamo in a certain position, the brushes and terminals will be of a polarity that corresponds to the position of the positive and negative magnet poles with reference to the armature. Removing the magnets and replacing them in a position exactly opposite to the one originally occupied while the direction of rotation remains the same will reverse the polarity of the dynamo brushes and terminals. This polarity can only be restored to normal by replacing the magnets in their proper position. No amount of flow from the battery through the dynamo will have any effect on the fields for the simple reason that this flow of current does not pass around or affect the fields in the same way as with the electromagnetic type previously discussed. A flow of battery current through the dynamo in a wrong direction, however, will serve to weaken the permanent magnets of this type of machine and every precaution should therefore be used to avoid wrong connections in the wiring.

The polarity of any wire or any terminal may always be determined by attaching extra lengths of wire to each of the terminals or each side of the circuit to be tested. If the loose ends of these wires be then immersed in water to which has been added a small

quantity of acid or salt, the wire attached to the negative side will give the greater amount of bubbles, Figure 16. The wire attached to the positive side will show very few, if any, bubbles. In making this

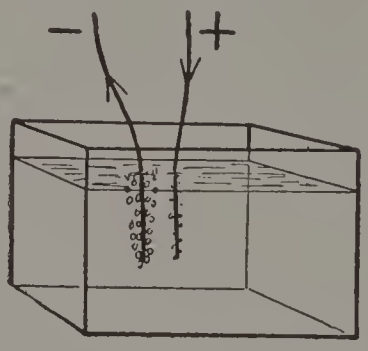


Figure 16.—Water Test for Polarity of Wire Ends.

test the wire ends should be separated by one-fourth to one-half inch. This test may be applied to dynamos while they are in operation, to batteries, or to any other wires when both sides of the circuit may be reached.

ARMATURE

With very few exceptions, all lighting dynamos are made with a form of armature known as the "drum

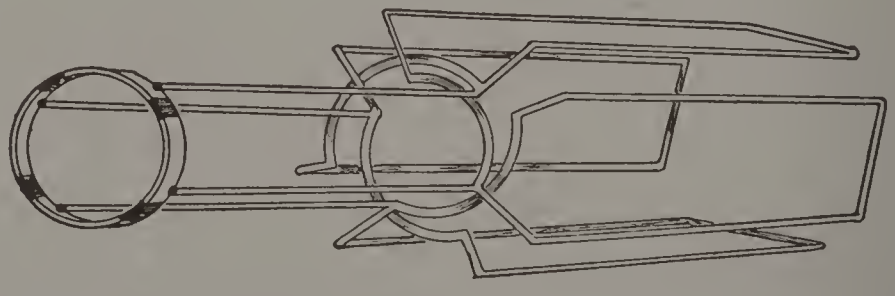


Figure 17.—Arrangement of Coils on a Drum Armature.

armature." The coil and commutator connections for this type are shown in Figure 17. This illustrates the principle used in handling the work by showing the connections for four coils and four commutator

bars. In actual practice this number is increased according to the size of the machine. It will be seen that the ends of one coil attach to adjacent commutator bars in such a way that all of the coils and all of the bars are electrically connected with each other. The bars are insulated from each other and the coils are insulated in each case, the interconnection being secured between coil and bar in each case, and not from coil to coil or from bar to bar. The design of such armatures is not important to the present discus-

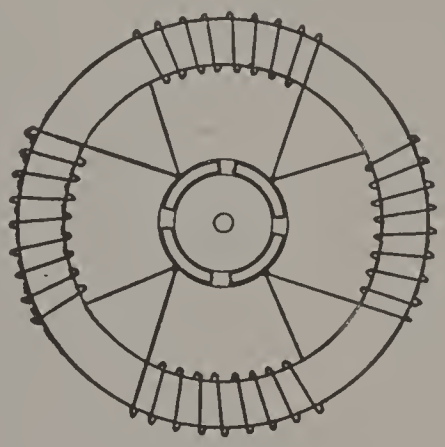


Figure 18.—Arrangement of Coils on a Ring Armature.

sion, but the connections should be understood because they make clear the results that are secured in certain tests.

Another form of armature sometimes found in this work is that known as the "Gramme" type, or the "ring armature." The construction and connections for such an armature are shown in Figure 18. The armature core is in this case a hollow ring in place of a solid cylinder, but the connections between the coils and commutator bars and the complete circuit around the whole armature remain practically the same in effect.

COMMUTATOR

This part of the dynamo, in connection with the brushes, changes the alternating current generated in the armature windings to a direct current suitable for battery charging. The commutator consists of a series of copper bars arranged in a ring around the armature shaft and separated from each other by strips of mica or other insulating material. The commutator segments are connected to the armature windings

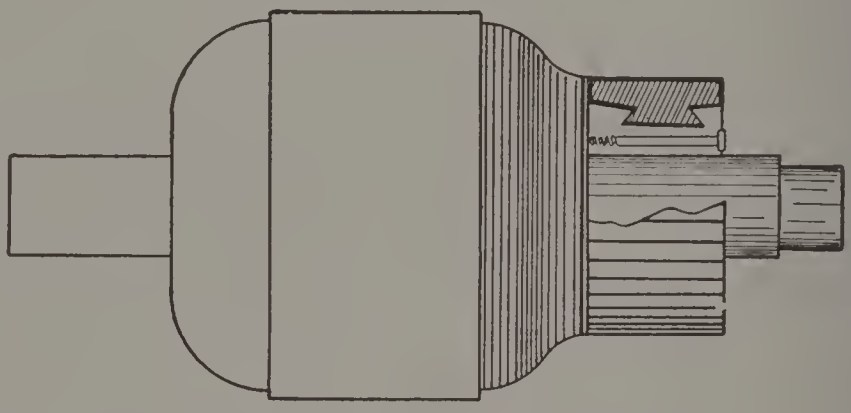


Figure 19.—Commutator Construction.

as shown in Figures 17 and 18 and the brushes are carried in holders in such a position that they bear on the surface of the commutator in the best positions for the collection of the current at proper voltage and amperage.

A longitudinal section through the commutator end of a dynamo armature is shown in Figure 19, this illustration indicating the proportions generally used for the commutator bars. It is necessary that the copper used be of a high degree of conductivity so that it will carry the current without undue heating and it is also necessary that the bars be of a depth sufficient to allow of a certain amount of wear from

the brushes before the surface of the commutator comes down too close to the insulation on which the bars are supported from the shaft.

It is very essential that the insulation between adjacent segments be perfect, otherwise the coil to which these segments attach will be short circuited and the operation of the dynamo will be affected.

In order that the brushes may make a good contact with the surface of the commutator, this surface must be maintained in proper condition. That means that the commutator surface must be smooth and perfectly cylindrical in the form generally employed. Should the surface become dirty, scratched, rough or pitted it must be restored to good condition at once if the dynamo is to be maintained in good condition.

The commutator surface should be of a rather dark brown color and should have a slightly glazed appearance when in the best condition. Should an examination show it to be blackened or dirty it may be cleaned by holding a soft cloth slightly moistened with gasoline against the commutator surface while the dynamo is being driven by the engine at the slowest possible speed. Oil should never be used on the surface of a commutator, but lubrication may be provided by placing a small quantity of vaseline on a piece of soft cloth or leather and holding it against the commutator surface with the dynamo revolving. Even this lubrication should not be used unless the commutator surface shows signs of scratching after being cleaned. In many makes of dynamos the brushes are made from a composition that provides sufficient lubrication for the commutator surface.

If the surface of the commutator is rough or slightly scratched and pitted it may be dressed smooth with

sandpaper. Emery cloth or emery paper should never be used because emery is an electrical conductor and will short circuit the commutator bars. Before using the sandpaper the commutator should be cleaned as described, the brushes should then be removed from their holders or the holders and brushes should be so supported that they do not touch the commutator surface. The engine should be run at the lowest possible speed so that the commutator is revolved. A strip of "000" sandpaper should then be cut just as wide as the commutator surface, no narrower under any circumstances, and this strip of paper should be placed over the end of a thin stick of equal width. By holding this paper against the surface of the revolving commutator slight scratches or pitting may be removed. Care should be used to bear evenly on the whole width of the commutator so that grooves may be avoided.

After the surface is even and bright, the engine should be stopped and every trace of copper dust and sand should be removed from the interior of the dynamo, either by wiping out with a cloth moistened with kerosene or by blowing out with air under pressure. The surface of the commutator will be improved and made very smooth if a soft pine stick is held against the surface while the engine is running. The job should be completed by dressing the ends of the brushes as described in a following paragraph.

Should the commutator surface show deep grooves or severe pitting it will be necessary to remove the armature from the dynamo, place it in a lathe and take the thinnest possible cut from the surface of the commutator. The comparatively slight thickness of the commutator bars should be borne in mind and

no more metal should be removed than is absolutely necessary to obtain a smooth surface.

After turning a commutator in the lathe it will be necessary to "undercut" the insulation between the segments. It will also be necessary to perform this operation should the insulation be found even with or slightly above the surface of the copper bars at each side. To undercut the insulation means to remove sufficient material from the exposed edge so that its surface is about 1/32 inch below the surface of the copper bars.

The removal of the insulating material may be effected by using a very thin hack saw blade and exer-

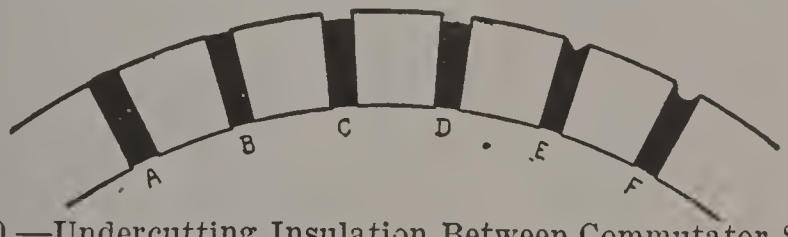


Figure 20.—Undercutting Insulation Between Commutator Segments.

cising great care to avoid bridging from segment to segment with fine particles of copper. Figure 20 shows a partial section through a series of commutator bars, the white spaces representing the copper segments and the black portions the insulating material. At *A* and *B* are shown pieces of insulation that require undercutting. At *C* and *D* are shown sections when the work has been properly done and at *E* and *F* when improperly done. When the insulation is removed it must be taken out so that the surface is flat and the corners made with the copper segments are square. A knife file should be used following the hack-saw blade so that the corners may be cleaned out. If the surface of the insulation is left grooved the work will be practically valueless.

Sparking at the brushes is usually caused by a commutator surface in poor condition, by improperly fitted brush ends, or by high insulation between the segments. Sparking may also be caused by brushes that do not rest on the commutator in the proper position, although this condition should not be met with unless the dynamo has been taken apart and wrongly reassembled. Other causes of sparking may be in the brushes themselves or trouble in the armature windings, which will be taken up in a later chapter.

While an examination of the commutator is being made it will be advisable to look carefully for segments that are loose, or too high or too low, that is, higher or lower than those adjoining. Loose segments will necessitate the return of the dynamo or armature to its makers, although high or low segments, provided this condition is not caused by looseness, may be corrected by turning the commutator in a lathe.

It will be noted that the wires coming from the armature windings are fastened to the commutator bars by soldering. These wire ends should be examined to make sure that they are tight, because the excessive heat that is sometimes generated in the dynamo may melt the solder and cause it to be thrown out of place. The remedy is to replace the wire ends and resolder them with hard solder and neutral flux.

BRUSHES

The brushes that collect current from the commutator are generally made from very fine grained carbon and this carbon is often combined with other substances such as graphite for purposes of lubrication and smooth running. Metal brushes made from

tightly wound coils of copper wire gauze are sometimes used, although they are comparatively rare. Brushes are sometimes made by placing carbon around a copper core, the use of any one type depending on the design of the dynamo and the ideas of the makers. Because of the fact that it is not always possible to know just what calculations and allowances have been made in the design of the machine, it is a safe rule to follow always to replace brushes with others secured from the makers of the machine being handled. While other brushes might be satisfactory, there is always a doubt.

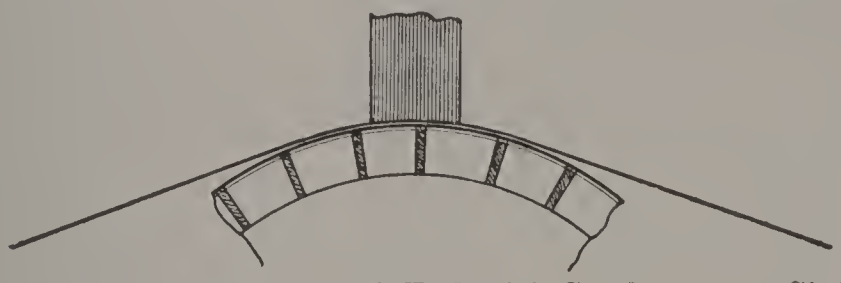


Figure 21.—Fitting Brush-End with Sandpaper or Cloth.

The electrical resistance between brush and commutator depends chiefly on how well the brush end fits the commutator surface against which it bears. High resistance lowers the efficiency of the dynamo and is the primary cause of more serious troubles. For these reasons the brush ends should always be properly fitted. This operation is performed as follows:

A strip of "000" sandpaper should be cut so that it is at least as wide as, and preferably a little wider than, the end of the brush to be handled. With the dynamo idle, the brush should be drawn away from the surface of the commutator so that the strip of paper may be drawn between the brush end and the commutator with the sand side toward the brush, Figure 21. The paper should then be drawn back and

forth under the brush end and should be held so that it follows the surface and curve of the commutator while passing under the brush. The sand will remove enough of the brush end to allow a perfect fit on the commutator surface to be secured. After all roughness and unevenness have been removed from the brush, the end should be carefully wiped with a clean soft cloth. All particles of dust should be removed from the interior of the dynamo with a cloth moistened with kerosene or by blowing them out with air. Each brush should be dressed in this way, even though only one seemed to need the treatment. Great care should be used in dressing the ends of regulating brushes (the use of which will be explained in Chapter V), and they should always be dressed after moving them to a new position. It is absolutely essential that the brush ends shall make perfect and full contact over their entire section.

The brushes are practically the only part of the dynamo that will require periodical replacement. It is not possible to state any definite time that brushes should last; this depends on the design and construction of the dynamo. They should be examined occasionally and their length noted. When it is seen that they can wear only one-eighth of an inch more before allowing their holders or springs to touch the commutator, they should be removed and replaced with new ones. A brush should be expected to wear at least a year, although this time may be affected by many conditions. New brushes should always be fitted to the commutator surface by the method described above.

The brushes are carried in the proper position by holders of various forms. Some holders fasten tightly to the brush and move with the brush as it wears and

as it follows the commutator surface, Figure 22. Other forms of holder provide that the brush slide freely in the holder, and in this case the holder itself remains stationary. In all cases the brushes are insulated from the holders or else the holders are insulated from the balance of the dynamo parts. Attached to the brush is a short length of flexible wire, usually called the brush "pigtail," and it is through this wire that the current is taken from the brush to the terminal connections, or in some cases, to a connection with the metal of the dynamo case for ground return systems.

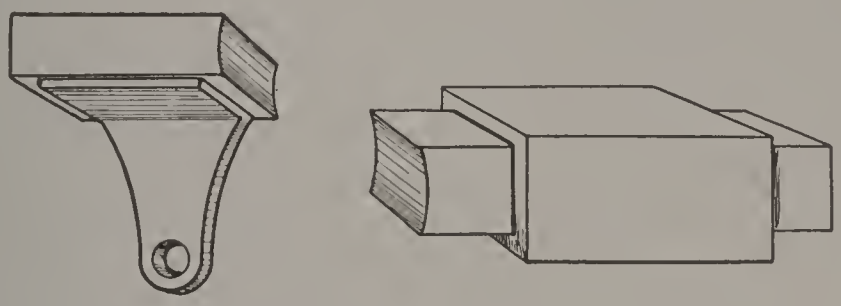


Figure 22.—Pivoted and Sliding Brush Holders.

The brush should be free to move at all times. If fastened securely to the holder, the holder should be free to move on the pivot that supports it, and if any binding is present, the dynamo output will be affected. If the brush slides in the holder, care must be used to see that the sides of the brush do not bind under any conditions. Should binding be found at this point, the sides of the brush may be carefully dressed with a fine file until a free sliding fit is secured.

The brushes are held against the commutator surface by means of springs of various forms and types. The tension of these springs is usually adjustable by some means, either by moving one end of the spring

from notch to notch of an adjustment segment, by tightening or loosening a holding screw or by some other easily discovered means. The tension on brushes varies from an ounce or two up to nearly two pounds, depending on the design and requirements. In all cases the tension should be sufficient to maintain a good running contact, that is, so that the dynamo output will not be impaired and so that spark-

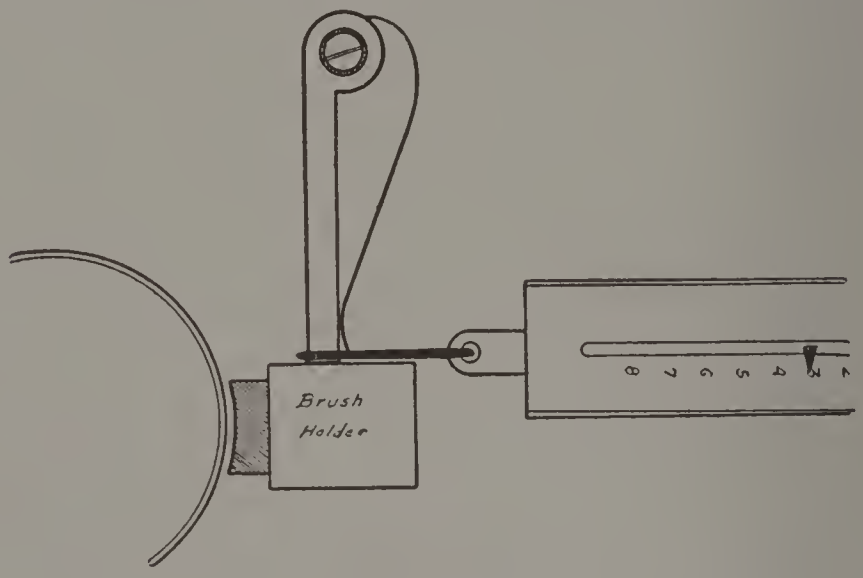


Figure 23.—Testing the Tension on Brushes by Means of Spring Balance.

ing will not take place with other factors taken care of. The tension should be as low as is possible and still secure good contact. More than this will cause excessive wear and overheating. See Figure 23.

STARTING MOTORS

The starting motor embodies the same principal parts as the dynamo, that is, it consists of an armature with its commutator, a set of brushes, field windings and field magnets. The most apparent difference between these units is in mechanical construction, the motor being heavier and being made from larger, stronger parts. Outside of the difference in action,

the most noticeable electrical change is in the method of connecting the field windings. For motors that are separate units, that is to say, motors that are not combined with the dynamo, the series field winding is invariably used because its characteristics are more desirable for the work of starting.

It will be seen from an examination of Figure 13 that a series winding would send all of the current passing through the machine into the fields and then this total flow of current passes through the armature. The magnetic strength of the fields becomes greater with increase of current flow and by thus sending the whole flow through the fields they are made of the greatest possible strength. The same statement applies to the armature, the great volume of current making the armature pull as great as can be secured.

The maximum flow of current through a starting motor varies according to the difficulty of starting the engine from rest, being large in some cases and comparatively small in others. At a pressure of six volts the starting amperage may be anywhere between seventy-five and three or four hundred. With higher voltages the amperage is reduced for the reason that the power is measured in watts and the same number of watts may be secured by using a higher voltage with a smaller flow.

The power required in starting is usually between one-half horsepower and two horsepower, depending on the size of the engine and its design. This starting load puts a very severe strain on the battery, and if the flow is allowed to continue for more than a few seconds, great damage may result. The form of battery used for this work is well able to stand these heavy discharges and it is not the amperage of dis-

charge that does harm so much as the withdrawal of such a great percentage of the available current from the battery. Fifteen minutes of rapid running will just about make up for the current drawn during thirty seconds' use of the starter with an engine that is rather hard to crank, and for this reason the starter should be carefully used and never demonstrated or used unnecessarily. The final result of improper use of the starter is a discharged battery, and it is this condition of discharge that harms the battery, not the heavy current drawn for starting.

In order to allow a motor of reasonable size to do the work it is connected to the engine through reduction gearing of some form. This gearing may take the form of chains or may be made up of spur, bevel or worm gears in combination with suitable shafting. The drive ratios ordinarily employed allow the starting motor to run from five to twenty-five times as fast as the engine crankshaft is revolved during the cranking operation. This ratio applies to starting motors that are separate units. Combined motor-dynamos usually have lower ratios, and in fact in some cases may operate at engine speed. A very common ratio for motor-dynamos is between two and one-half to one and three to one.

MOTOR-DYNAMOS

This word is used to designate the machines that are combined electrically, having one or more parts that perform functions during the generation of current as well as during the starting operation. The machine in which a separate motor and dynamo are enclosed by the same housing is not called a motor-dynamo in this book.

In all motor-dynamos it is necessary to provide two field windings, one a series winding for starting motor action and the other a shunt winding for the efficient generation of current, Figure 24. In some cases an additional winding is used for the purpose of regulating the output of the machine as a dynamo. In this last case the field magnets will carry a shunt winding for generating, a reversed series winding for output control and another series winding of heavier conductor for starting the engine as a motor. This system is used in Splitdorf motor-dynamos.

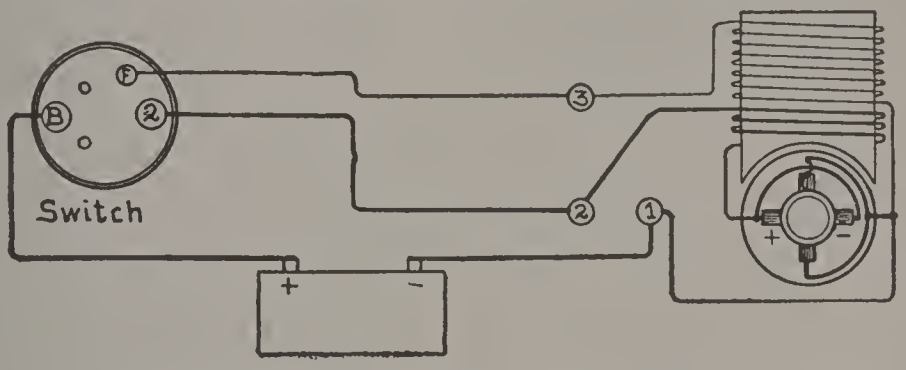


Figure 24.—Compound Wound Motor-Dynamo (Ryneto Type).

Other designs make use of a third field winding for purposes of regulation, but do not use the reversed series connection. One of these is found in the U. S. L. system which incorporates a compensating coil on one of the field magnet poles, this coil being energized through the current drawn off the commutator by a regulating brush. The action of this compensating coil is to assist the shunt windings at low speeds, but to oppose them at high speeds because of the change of direction in the current flow through the regulating brushes.

Motor-dynamos make up a very important class and also a very large proportion of the applications in use. They may be divided into several types, according to

their construction and the principles involved in their operation. While the two types just mentioned partake somewhat of the characteristics of those to be mentioned hereafter, they should be considered separately because of the additional field winding that is used to produce the regulation of current.

One of the commonest classes of motor-dynamos is the one making use of a machine with one armature with one commutator for both starting and charging. The fields carry a shunt and a series winding. Dur-

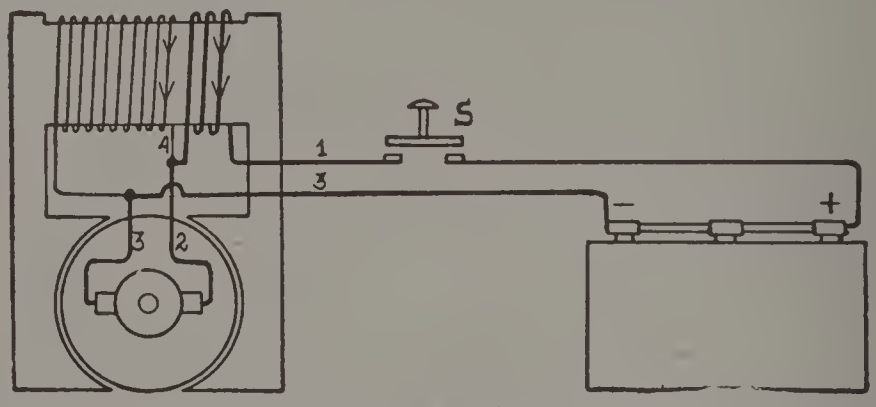


Figure 25.—Compound Wound Motor-Dynamo Providing Reversed Series Regulation.

ing the starting operation the current flow passes through these windings in such a direction that they assist each other and the machine becomes a compound wound starting motor. When the speed of the motor-dynamo is increased to a point at which its generated voltage will overcome the battery voltage, it becomes a dynamo with the shunt field current flowing in the same direction as during starting, but with the series field current flowing in the opposite direction. This makes it a dynamo with a reversed series field coil, and this reversed series winding serves to limit the amperage during charging. This action is shown in Figure 25. When the starting switch *S* is closed, the

battery current flows through the positive wire *1* and around the series field winding in the direction of the arrows, thence through the wire *2* to the right-hand brush, through the armature to the left-hand brush and to the battery through the negative wire *3*. The right-hand brush is positive and the left-hand one negative. Current then flows from the positive brush side through the wire *4* and around the shunt field coils in the direction of the arrows and back to the negative brush side. It will be seen from the arrows that the current flow is in the same direction around both field windings.

Now consider what happens when the dynamo voltage overcomes that of the battery. The flow of current will then be from dynamo to battery and at the instant of reversal there will be no flow through the series field, although the flow will continue through the shunt coils. This is true because the current stops coming from the battery and for a moment might be said to stand still in the lines connected to the battery. The dynamo voltage is now causing a flow through the shunt field in the original direction and because the fields are maintained with the same polarity the right-hand brush remains positive. With the flow from dynamo to battery, the direction of current through the shunt coils will be as shown by the arrows, but the flow through the series field will have been reversed and will be in the direction opposite to the arrows, which of course causes the upper coils to become a reversed series winding. A reverse current cut-out may or may not be used with this system. Some makers, such as Allis-Chalmers, use an electromagnetic cut-out, while others, like Dyneto and Entz, allow the dynamo and battery to remain connected as

long as the starting switch is closed. This subject will be more fully covered in Chapter V.

Another class of motor-dynamos makes use of a series and a shunt field winding, but with the difference that the series field is not used as the principal method of current control, while the shunt field is neglected, or is of minor importance, during charging. These machines make use of an automatic cut-out in the charging circuit which opens the connection between battery and dynamo when the dynamo voltage

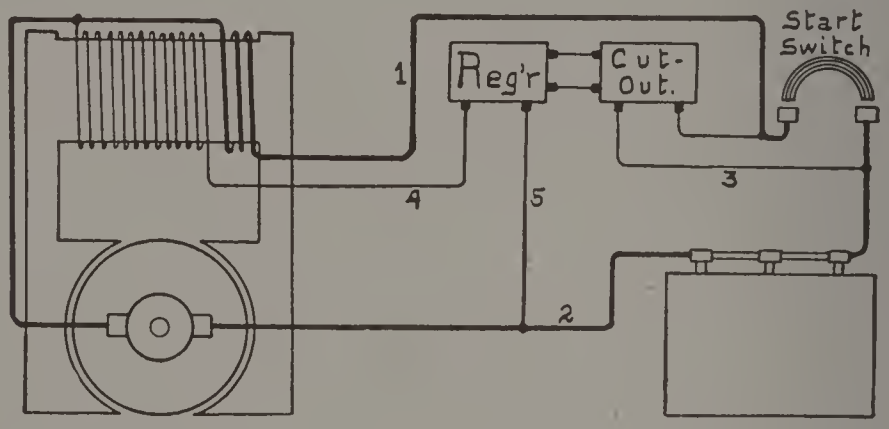


Figure 26.—Motor-Dynamo with Separate Regulator and Cut-Out.

is below that of the battery and while the starting switch is open. The connections for such a system are shown in Figure 26, which illustrates the principle involved, although in practice the wiring is not always placed exactly as shown for manufacturing reasons. With the starting switch *S* closed, current flows from the battery through the wire *1* and the series field to the left-hand brush, then through the armature to the right-hand brush and back to the battery through the wire *2*. When the engine has been started and the starting switch opens, the battery is disconnected from the motor-dynamo by the open starting switch and by

the cut-out which is always open when the dynamo voltage is below that of the battery. When the dynamo is running at a speed sufficient for charging, the cut-out closes and the dynamo and battery are connected through the wires *1* and *3* on the positive side, and the wire *2* on the negative so that charging commences. It will be noticed that the shunt field wire leads to the regulator and the dynamo output is controlled by the action of this regulator in limiting the shunt field current. The current from the left-hand brush passes to the shunt field, then through the wire *4* to the regulator and back through the wire *5* to the right-hand brush. The current that flows through the series field to the cut-out during charging passes in a direction the reverse of that found during starting so that this series field acts to limit the dynamo amperage. This action is not depended on altogether, but the additional regulator in the shunt field circuit is supposed to perform this function. This is the principle used with Allis-Chalmers motor-dynamos, also with North-East, Remy, and Simms-Huff units.

Other motor-dynamos use an automatic cut-out, but control the dynamo output by other means than the one shown in Figure 25. For example, Wagner, Bijur, and Westinghouse motor-dynamos use the "third brush" method of control, while Jesco motor-dynamos make use of a "bucking coil" on the field magnets, both of which methods of control will be explained in Chapter V.

Still another class of motor-dynamos, represented by Delco equipment, makes use of a shunt and a series field winding and also provides separate windings and two separate commutators for the armature. The principle of connection used with such a machine

is shown in Figure 27. With the engine idle the open cut-out switch disconnects the battery from the brushes on the dynamo commutator *D* and also from the lower shunt field. The dynamo or current generating part of the unit is therefore inoperative. When the starting switch *S* is closed, current flows from the battery through the wires *1* and *2* to the upper series field and then through the wire *3* to the brush resting

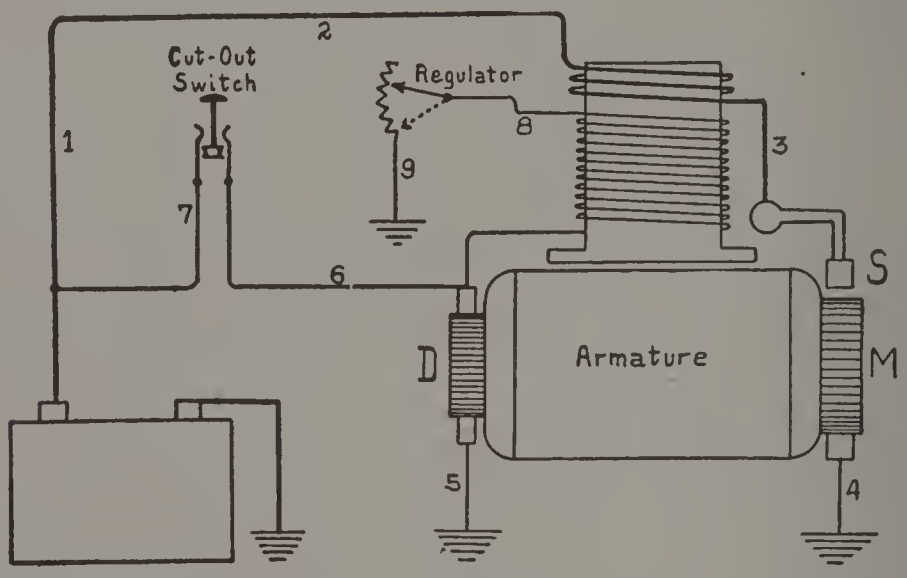


Figure 27.—Double Commutator Motor-Dynamo with Manual Cut-Out (Delco Type).

on the motor commutator *M*. Passing through the motor windings on the armature, the current returns to the battery through the wire *4* and the engine is started.

With the engine started, the switch *S* is allowed to open and the series field and motor windings on the armature are no longer energized. The motor-dynamo is then driven by the engine as a dynamo and with the cut-out switch closed, current flows from the dynamo commutator *D* through the brushes and wires *5*, *6* and *7* to the battery for charging. The shunt

field is connected to the dynamo commutator brushes and the flow through the field windings is controlled by the regulator. The shunt field current passes from the upper brush through the field windings, then through wire *8* to the regulator and back through wire *9* to the lower dynamo brush.

COMBINED UNITS

While the separate dynamo and motor, together with the motor-dynamo, make up by far the greater part of all the equipments in use, other combinations

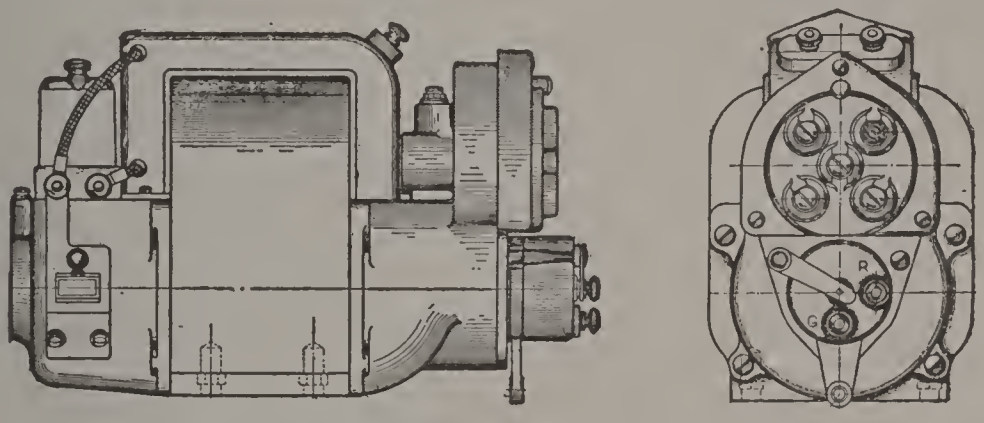


Figure 28.—Ignition-Dynamo (Remy).

are found in lesser numbers. One of these is the ignition-dynamo. This machine is made by attaching to a separate dynamo of any type the devices that are necessary for the production and distribution of the ignition current for the spark plugs.

One type of ignition-dynamo, Figure 28, makes use of a breaker, or interrupter, and a high tension distributor of the conventional magneto type mounted on one end of the dynamo, either the end that carries the dynamo commutator and brushes or the opposite end. The operation of these ignition parts differs in no way from the operation of similar ones used on magnetos, the attachment to the dynamo being made simply be-

cause it affords an economical method of mounting and does away with the necessity for providing a separate magneto with its drive and base. The combination of these ignition parts in no wise affects the starting and lighting features of the machine and in this connection the ignition units may be disregarded. It should be understood that this construction does not allow for what is known as a "self-contained high-

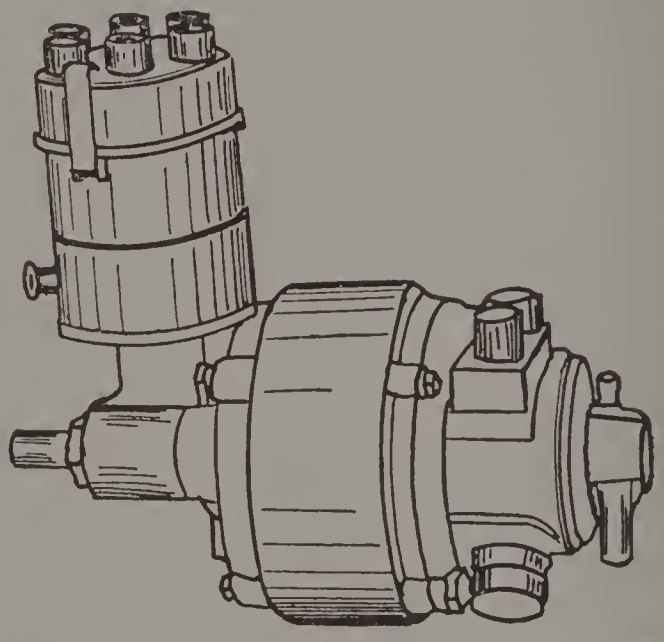


Figure 29.—Dynamo with Vertical Ignition Head (Westinghouse).

tension" magneto being incorporated with the dynamo, but uses a separate transformer coil just as does the magneto of the type that requires a separately mounted coil. This type of machine has been produced by Gray & Davis, National, Remy, and Westinghouse.

Another consolidation of electrical devices is met with when the ignition units are mounted on the dynamo case and are driven from the same shaft that drives the dynamo, Figure 29. In this case the ignition parts include a breaker or interrupter together

with a high tension distributor carried in a small housing and with their drive shaft attaching through gearing in the dynamo drive shaft. The separate transformer coil may be mounted on the dynamo or may be carried at some other point on the car. This combination is also called an ignition dynamo or "dynamo with ignition."

It is also possible to mount the type of ignition units just described on a motor-dynamo just as they are mounted on a dynamo. This is the construction so often found with Delco installations, Figure 30, and has also been used by such makers as Remy. A single piece of machinery then performs functions of starting, lighting and ignition, and is often called a single-unit machine. The term "single unit" is commonly applied to the motor-dynamo also, although its use in this connection is somewhat confusing. The various combinations may be distinguished by calling a system made up of separate dynamo, separate motor and separate ignition unit, a "three-unit" system; a motor-dynamo or ignition-dynamo with separate ignition or motor, a "two-unit" system; and a motor-dynamo with ignition a "single-unit" system.

The combination of motor and dynamo in one case while making them separate electrical units is in fairly common use. The electrical design of the parts of the installation does not differ in any way from that used when they are placed entirely away from each other. When this construction is used, the dynamo unit is generally driven from the shaft or chain sprocket that comes direct from the engine crankshaft, so that a proper drive ratio for the dynamo may easily be secured. The motor is then mounted at one side, or above or below the dynamo,

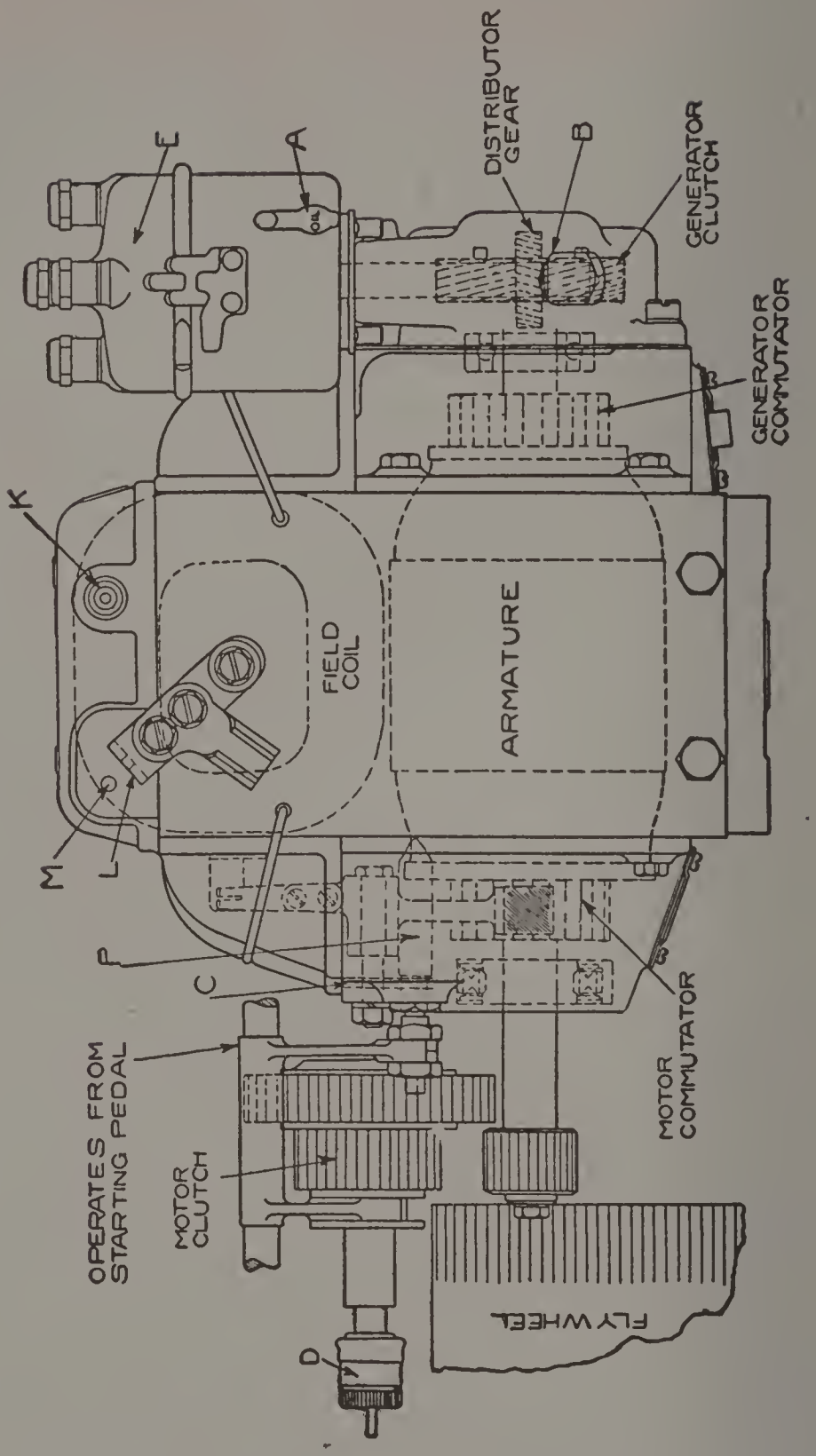


Figure 30.—Delco Motor-Dynamo with Ignition Head.

and drives to the main dynamo shaft through a reduction gearing that allows of the proper ratio for starting without interfering with the dynamo drive. See Figure 31. The dynamo is always driven while the engine is running because of its direct connection with the main drive shaft. The motor, however, is only in operation while the engine is being started and at all other times is allowed to remain idle and dis-

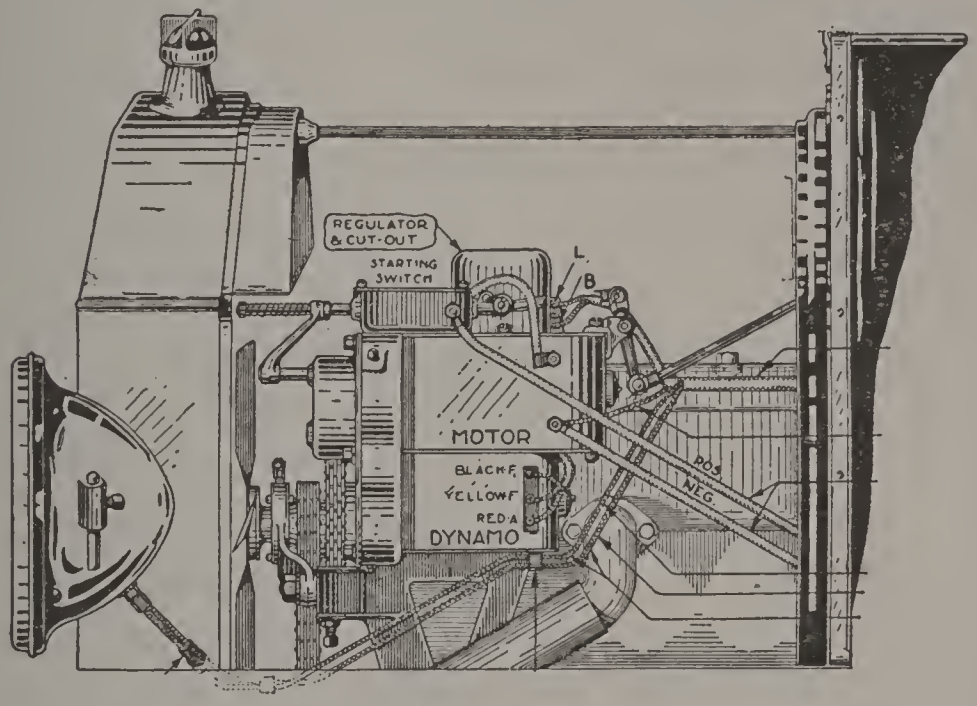


Figure 31.—Double Deck Motor and Dynamo (Gray & Davis).

connected from the drive shaft. The location of the units and the construction used with them will always be apparent from an examination.

Some modifications of the types described are in use, such as the tandem system, which places the motor and dynamo end to end. They are mechanical variations only and are not important from the electrical standpoint. Many such combinations are adopted because of the limited room or difficult drive connections that must be considered.

CHAPTER III

STORAGE BATTERIES

Each cell of a storage battery contains two kinds of plates, called positive and negative, made from compounds of lead and immersed in a liquid composed of sulphuric acid and water. A chemical action takes place between the plates and the liquid and the result of this chemical action is a flow of electricity through wires that are attached to the battery terminals. Therefore, the battery does not store, and does not contain, electricity, but is capable of generating a flow of electric current because of the action that takes place in the battery. In order to bring the elements of the battery into such condition that they will cause a flow of current, it is first necessary to send a flow of electricity through the battery. The energy of this current being sent through the battery is consumed in making one series of chemical changes, and when wires are connected to the battery, this same series of changes takes place in a reverse order and most of the energy absorbed from the flow of charging current is given back into the wires.

As already mentioned, the cells are made up of plates and liquid. The plates are in turn made up of a metal framework, called the "grid," Figure 32, and a paste, called the active material, with which the spaces in the grid are filled. Adjacent plates are prevented from touching each other by the use of wood separators, Figure 33, placed between them.

The jar in which the plates, separators and liquid are carried is made from some form of insulating material, often containing rubber, compounds of pitch and other materials that insulate while resisting the action of the acid in the liquid.

The grids are made from lead with which has been alloyed antimony to give the metal the necessary stiffness. Various designs and forms are in use, but they consist in a general way of vertical and horizontal

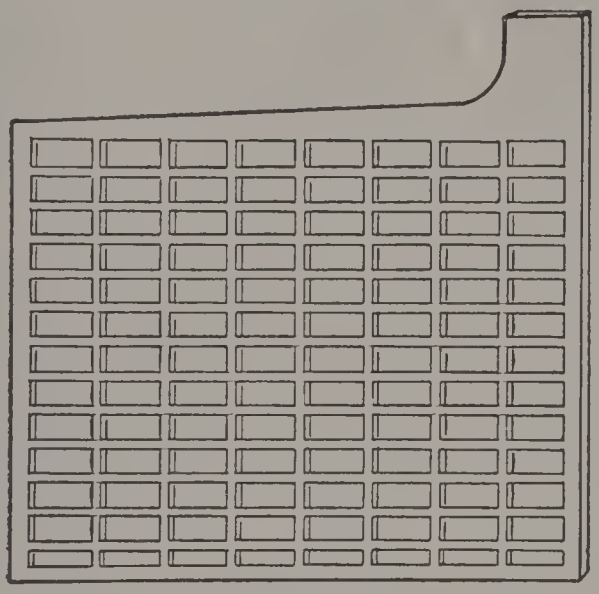
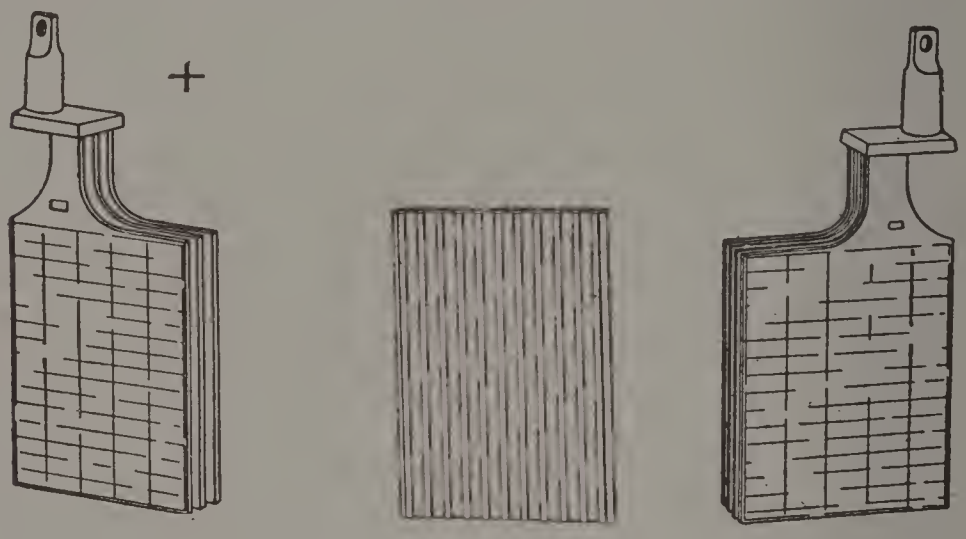


Figure 32.—Grid for Battery Plate.

bars usually spaced about three-fourths of an inch apart, measuring across the plate and about one-fourth inch apart measuring up and down. The grids, and consequently the plates, vary in thickness from about one-eighth inch up to three-eighths. The thickness of the plate has a great deal to do with the rate in amperes at which current may be drawn from the battery. Very thin plates allow the liquid in the cell to reach through them with comparative ease and a very heavy current may be taken from such a battery, while the thicker plates will only allow comparatively

low amperages to be drawn through the wires. The bars of the grid are formed and spaced in such a way that they tend to hold the active material firmly in place.

After the grids have been formed they are filled with the active material by the process called "pasting," and this form of plate is called a "pasted plate." The active material is made from lead oxides, sometimes combined with other materials to give hard-



Figures 33 and 34.—Positive Plates, Separator and Negative Plates.

ness and toughness and to make the plates porous so that the liquid can act on the material. The mixture is made into a paste with weak solutions of sulphuric acid and water, and the spaces between the bars of the grid are filled with this paste. After the material has set or hardened, the pasted plates are assembled with their separators in a jar. The cell contains an uneven number of plates, Figure 34, there being one more negative than positive, and the plates are placed alternately and so that both outside plates are negative. The liquid, composed of acid and water, is then poured into the jar until it covers the plates to a

depth of one-quarter to three-eighths of an inch above their upper edges.

When the cell has been assembled all the positives are joined together and all of the negatives are similarly fastened together with connecting straps that join the lugs cast at one of the upper corners of each grid. The positive connecting strap is attached to the positive terminal of the cell or battery, while the negative strap is fastened to the negative terminal.

A flow of electric current is then sent through the cells, the positive side of the charging current being attached to the terminal that will be positive and the negative side of the source of current being connected with the negative terminal. As this current flows through the cells a change takes place in the material of the plates and the positives turn to peroxide of lead while the negatives turn to sponge lead. When the material in the grids has been completely transformed, which usually takes several reversals of current flow, the plates are said to be "formed" and the battery is charged.

The positive plates are now dark red or brownish red in color and are hard enough to resist scratching with the finger nail. The negatives are gray and are soft enough to be easily dented with any hard substance. The material must be porous in each case, and water poured on dry positive plates should show through on the opposite side almost immediately. It is very desirable that the material in the plates be as tough as possible, so that it will not readily fall to pieces, and it should also be as lightweight as possible so that the surface exposed will be large when compared to the total weight. High grade batteries of these types will deliver a power of between nine and

twelve watt-hours for each pound of weight, this being the equivalent of from one and one-half to two amperes flow at six volts pressure. The battery will gradually deteriorate while in use, and when its age is between eighteen months and three years, the negative plates will have suffered a change in the form of the material so that it is an economy to replace the battery with a new one.

THE CELL

Inasmuch as all batteries must be made up of individual cells and as all the cells in one battery are exactly alike, the subject will be treated as the cell rather than the battery, and it will be understood that everything said about the cells applies to the battery as a whole.

The voltage obtained from one cell does not depend on the size or weight of the cell, as it is the same whether the battery will give a flow of only a few amperes or of several hundred amperes. The normal voltage under operating conditions is two for the cell, this voltage varying, however, with the state of charge of the battery. When the material in the plates has been completely changed to peroxide of lead and lead sponge and the cell is fully charged, the cell voltage may be as high as 2.5, while with the battery discharged to a point at which no more current should be drawn, this voltage will fall to between 1.7 and 1.8 for the cell. The voltage while being charged will be higher than while being discharged, the charge voltage being between 2.1 and 2.6, while on discharge the voltage will usually run between 1.9 and 2.1. It will thus be seen that the voltage of the cell may give some indication of the condition of charge or discharge, a

voltage below 2 indicating that the cell is discharged, while a voltage of 2 or more indicates a satisfactory condition of charge. It should be understood, however, that the voltage does not form an entirely dependable indication because it is easily possible to have a high voltage with a cell that is capable of giving very little flow of current for useful work, while the voltage of a cell that is in good condition to do a great deal of work may be rather low. In making ordinary calculations it is customary to consider each cell as causing a pressure of two volts. Therefore, a

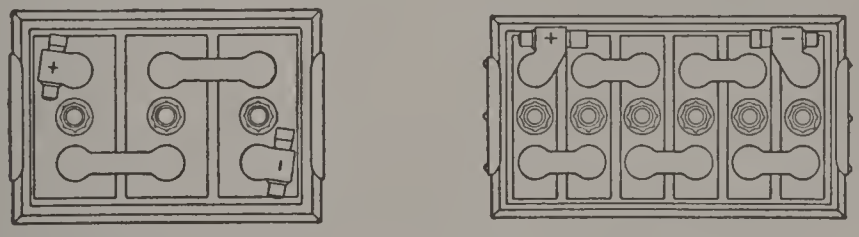


Figure 35.—Six- and Twelve-Volt Batteries with Cells in Series.

three-cell battery is called a six-volt battery, a six-cell battery is a twelve-volt battery, etc. It should be borne in mind that a six-volt battery may give a pressure of seven and one-half volts, a twelve-volt battery may give fifteen volts, and so on for any voltage or number of cells.

In order that the voltage of the whole battery may be equal to the number of cells multiplied by two, the individual cells are connected in series with each other. The series method, Figure 35, connects the positive of one cell to the negative of the next and the positive of the second to the negative of the third, and this connection is carried throughout the battery if it is desired to secure a voltage equal to the combined voltages of all the cells. It is possible to make other

connections that will give a lower total voltage by placing a sufficient number of cells in series to give the desired pressure and calling these cells one section of the battery. Two of these sections placed with the positive terminals of the sections together and the negatives together, Figure 36, will give a voltage only equal to that of one section, and the two parts are then connected in multiple or parallel. This method of connection is used in some electrical systems that fur-

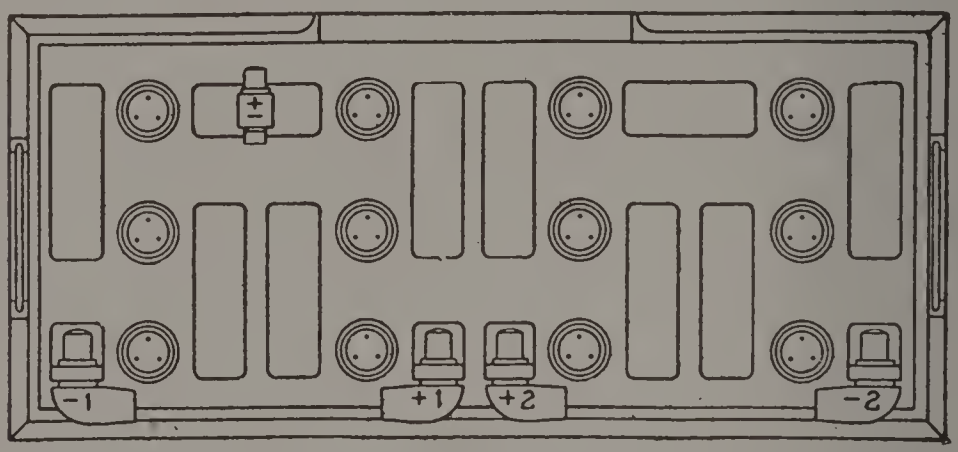


Figure 36.—Twelve-Cell Battery of Two Sections for Multiple Connection. —1 and +1, Terminals for Left-Hand Section. +2 and —2, Terminals for Right-Hand Section. Terminal Marked + and — on Left-Hand Section Is for a Neutral Wire to Provide Six-Volt Pressure.

nish a high voltage for starting purposes and a lower voltage for lighting and battery charging.

Batteries are in use having three, six, eight, nine, twelve or fifteen cells and giving respectively six, twelve, sixteen, eighteen, twenty-four or thirty volts. All of these except the three-cell type may be divided into two sections or more. (See Figure 37.) Six-cell batteries are made to give either twelve volts or else six and twelve according to their connection. Eight-cell batteries always are arranged to give eight or sixteen volts. Nine-cell batteries may give eighteen volts or may be arranged to give six, twelve and

eighteen volts. Twelve-cell batteries may be arranged for twelve and twenty-four volts or for six and twenty-four volts. Fifteen-cell batteries are arranged to give six or thirty volts. The higher voltage is always used for starting the engine, while the low voltages are for lighting or for lighting and charging.

The current that a cell will give is measured in ampere-hours or in watt-hours, generally by the former. An ampere-hour is the total quantity of current that passes in one hour if the flow is continuous at a

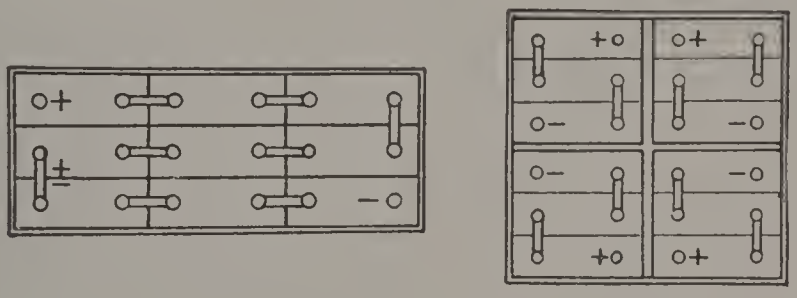


Figure 37.—Nine-Cell Battery (Left) with Neutral Terminal, and Twelve-Cell Battery (Right) Divided Into Four Sections.

rate of one ampere. An ampere-hour will also pass if a flow of one-half ampere is maintained for two hours and likewise one ampere-hour will pass if a flow of two amperes is continued for one-half hour or of four amperes for a quarter of an hour. The number of ampere-hours is found by multiplying the number of amperes flowing by the time in hours that the flow continues. Batteries are generally rated according to their ampere-hour capacity, this capacity being based on discharging the battery in eight hours. A battery rated as a 120 ampere-hour battery would give a flow of one ampere for 120 hours, or, theoretically, a flow of 120 amperes for one hour. This latter flow could not be secured in practice, however, because of the

action that would take place in the cells under such a heavy discharge rate. The 120 ampere-hour battery should give a flow of fifteen amperes for eight hours, thus giving its normal output of 120 ampere hours. At low rates of discharge, that is, with a less number of amperes flowing, it will be possible to secure more than 120 ampere-hours, while a high rate will decrease the available number of ampere-hours.

Batteries vary in capacity according to the size and weight of the plates that are in the cells and according to the number of plates used. The greater the positive plate surface exposed to the liquid in the cells, the greater will be the ampere-hour capacity of the cells. Batteries of three cells for automobile use range in capacity between sixty ampere-hours and one hundred and eighty ampere-hours, depending on the lamp and other equipment that must be handled. Batteries of more than three cells are of less amperage in proportion to the increased voltage, although the watts that may be secured will remain the same regardless of the combination of voltage and amperage used.

The watt-hour capacity may be found from the ampere-hour capacity by multiplying this latter figure by the voltage. One watt-hour is the power secured from a flow of one ampere under a pressure of one volt (equalling one watt) for one hour. A six-volt battery of eighty ampere-hours' capacity would therefore have a capacity of 480 watt-hours.

BATTERY CHARGE AND DISCHARGE

As previously stated, a charged cell has had its positive plates changed to peroxide of lead and its negatives to sponge lead. The liquid in the cells,

which is made from a mixture of sulphuric acid and water, is called the electrolyte. The peroxide plate, the sponge plate and the electrolyte make up the working parts of the cell.

When the battery is connected to the wiring circuits of the car so that it starts the engine or lights the lamps, an action immediately begins to take place in the cells and between the plates and the electrolyte. A part of the sulphuric acid in the liquid begins to combine with the lead in the plates to form lead sulphate, and the surfaces of both plates are gradually covered with this sulphate. The percentage of water in the electrolyte is increased because of the combining of part of the oxygen and the sulphur of the acid with the lead of the plates, leaving the hydrogen and oxygen in the form of water, which is a combination of these two gases. The surfaces of the plates thus change slowly to lead sulphate, while the liquid becomes more nearly pure water. When this action has penetrated a slight distance below the surfaces of the plates, the coating of sulphate causes the change to take place at a slower rate, and the battery will then give a smaller flow in amperes and at a lower voltage. When the discharge has continued until the normal output of the battery has been secured, damage will be done by further discharge, and it will then be necessary to send a charging current through the cells in a direction the reverse of the flow that takes place during discharge. The water analogy can be used here, comparing the battery to a tank that has been emptied and into which a flow of water must be sent in a direction the reverse of that taken by the water that was discharged from the tank.

With the charging current flowing, the sulphate

of the plates combines with part of the hydrogen and oxygen in the liquid to form sulphuric acid. The positive plate then becomes peroxide of lead and the negative is left as sponge lead. This transformation continues until the sulphate is completely reduced, and the battery is then said to be charged. Further flow of current will not increase the charge nor the flow that may be drawn from the battery on discharge. It should be understood that the sulphate referred to here is not the injurious form that attacks the plates when they are said to be "sulphated," as a disease or trouble. Plates that are "sulphated," in the latter sense, are over-sulphated, and the deposit is then an almost pure and practically insoluble lead sulphate that prevents proper action in the cells.

The rate of flow through the battery while being charged depends on the ampere-hour capacity of the battery, and should never exceed a number of amperes equal to one-eighth of this capacity. That is, an eighty ampere-hour battery should not be charged at a rate in excess of ten amperes, or one-eighth of the total capacity.

The efficiency of a battery is greater with low rates of charge and discharge than with high rates. By efficiency is meant the proportion of current that may be withdrawn from a battery in comparison with the amount sent in on charge. The conditions of use on an automobile are favorable from an efficiency standpoint in some ways, although the conditions are hard on the battery in others. The action on the car is to give some charge while the dynamo runs and then some discharge as the lamps burn. Oftentimes the battery will be required to absorb the excess of dynamo output above the current being taken for the lamps,

and at other times the battery will be called upon to make up a slight deficiency between the lamp load and dynamo output. This use of the battery is called "floating" it in the lines, and it is known that the efficiencies of floating batteries are higher than for those that are completely charged and then completely discharged.

The rate of discharge should not exceed in amperes one-eighth of the ampere-hour capacity of the battery, although rapid discharge is not very harmful to a battery provided it is not then allowed to stand in a discharged condition. The efficiency of the battery, if called one hundred per cent at a discharge rate of one-eighth of its capacity, drops with increase of discharge amperage until at one-sixth of the ampere-hour capacity the efficiency is about nine-tenths. At double the eight-hour rate, or one-fourth of the total capacity, the efficiency is about four-fifths, while a discharge that would empty the battery in one hour will allow less than half of the normal number of ampere-hours to be secured.

The greatest care that is necessary in allowing a battery to discharge is to see that it does not do so to such a point that the voltage becomes abnormally low. Under no conditions should discharge be continued when the voltage is 1.7 per cell, and if the current flow from the battery is carried past this point serious damage will result from over-sulphation on the plates, distortion and warping of the plates, and the formation of harmful corrosion on the metal of the grids.

The proper charging rate for the different batteries may be found from the information given on the nameplate attached to the battery case. In most

cases two different rates will be given, one marked "start," and the other "finish," or "24-hour." The starting rate is the greatest that the battery will stand, and should be as great as the highest rate of charge that the dynamo can send through the battery. The finish rate is used when the battery is charged from an outside source of current other than the car's dynamo. The high rate is between one-sixth and one-tenth of the capacity in ampere-hours, generally about one-eighth. The finish rate is approximately one-fourth to one-half of the high rate, generally about one-third.

When it is necessary to charge a battery from an outside source, it must be remembered that the positive side of the charging current must be attached to the positive terminal of the battery and the negative of the charging current to the negative of the battery. The polarity of any wires may be determined by immersing their ends in water to which has been added a small amount of acid or salt. The wire that comes from the negative side of the source will bubble most.

The charging current must always be direct current. Alternating current connected directly to the battery without the use of a rectifier will not only fail to charge the battery, but will do positive damage. Direct current is abbreviated, D. C., and alternating current, A. C. It will be necessary to ascertain which kind of current is supplied by the charging circuit to be used, and if it is alternating, a rectifier must be inserted between source of current and the battery to be charged.

With a supply of direct current at hand, the battery may be charged by inserting such a resistance in the line as will allow the proper amperage to flow through

the cells. The high voltages found on lighting and power circuits in buildings would send a damaging flow through the cells, and it will always be necessary to use incandescent lamps or other forms of resistance with such current and voltage. (See Figure 38.)

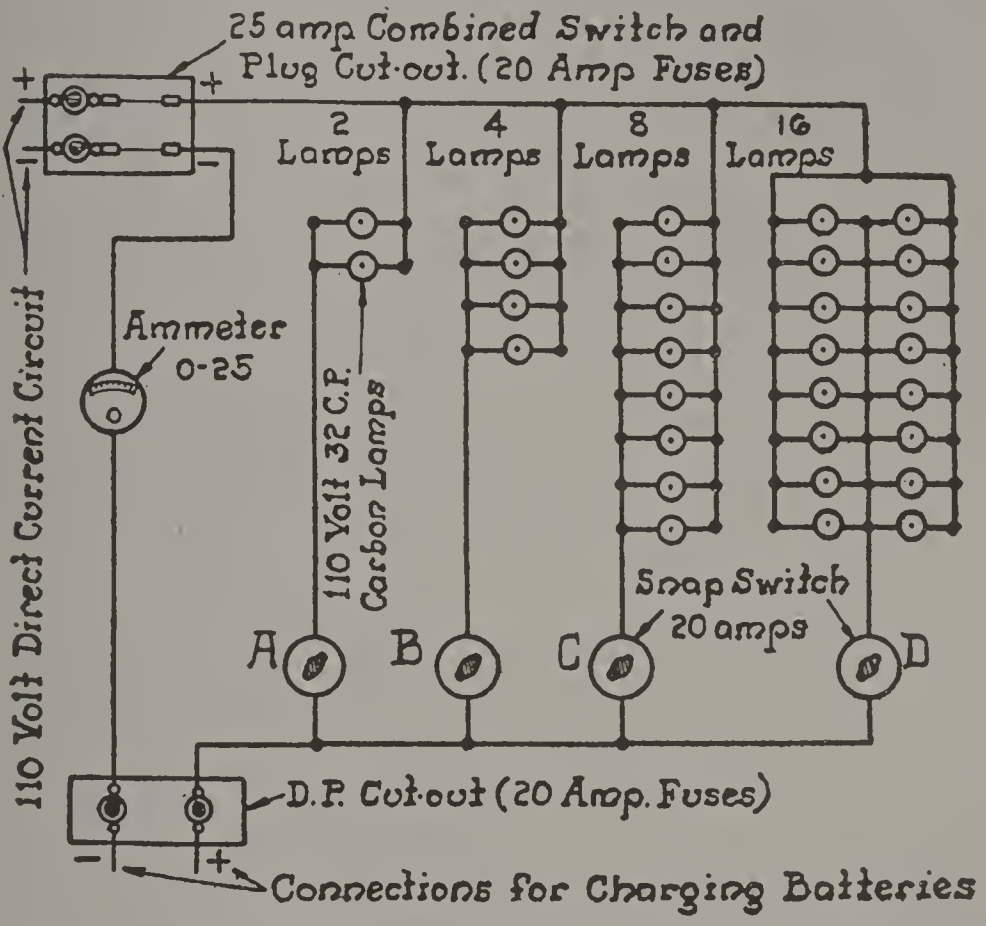


Figure 38.—Battery Charging with Lamps for Resistance.

A sufficient number of incandescent lamps may be lighted at one time to allow the amperage to flow at the rate marked "finish," or "24-hour." If the lamps to be used are marked on their bulbs with the number of watts required, as is usually the case, enough lamps must be lighted to give a total number of watts when added together that will allow the proper amperage to flow. The amperage desired should be multiplied

by the voltage of the charging line, this giving the number of watts required. Enough lamps must then be used to make up this number of watts. Thus, if the battery requires three amperes charge and the charging current is 110 volts, three times this voltage gives 330 watts as the result. Seven 50-watt bulbs will make 350 watts, which will be just about right. If the lamp bulbs are marked in candlepower, their wattage may be found by multiplying the candlepower by three for carbon filament bulbs, or considering a 16 c.p. bulb as a 50-watt bulb and a 32 c.p. bulb as a 100-watt bulb, etc. If tungsten lamps must be used, the candlepower and wattage are equal, that is, a fifty-candlepower bulb is a fifty-watt bulb.

A battery should have each cell filled with pure water until the level is above the tops of the plates before any charging is done; this applies whether the battery is charged on the car or from an outside source. When giving an outside charge it is desirable that the current should flow without interruption until the charge is complete.

ELECTROLYTE AND TESTING

From the explanation given of the action that takes place during charge and discharge, it will be seen that the proportion of acid in the electrolyte will give an indication of the condition of the battery, that is, whether it is properly charged or nearly discharged. The acid is much heavier than water, and as the proportion of acid in the liquid becomes greater, the weight of the electrolyte becomes greater. Therefore, the heavier the electrolyte, the more nearly charged the battery is known to be.

To find the condition of the battery by testing the

liquid, a hydrometer is used. The hydrometer (Figure 39) is a glass tube having a hollow bulb and a weight at one end and a thin tube with a numbered scale at the other end. When this instrument is

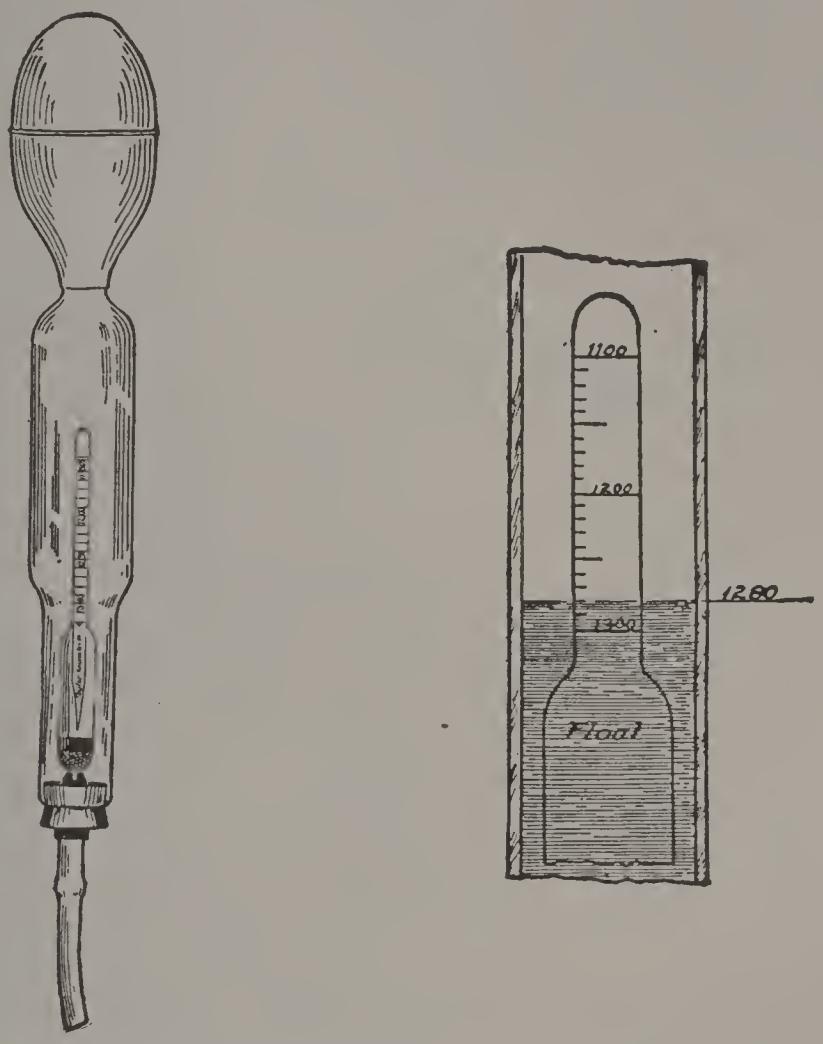


Figure 39.—Hydrometer Syringe and Hydrometer.

allowed to float in the liquid from the battery cells, the point on the scale to which it sinks indicates the weight of the liquid, because, of course, the hydrometer will not sink so deep into the heavy liquid with a large proportion of acid as it will into the liquid when almost all water. The scale is graduated accord-

ing to the weight of liquids, known as specific gravity, which is their weight compared to that of pure water. On the stem of the hydrometer appear numbers from 1.100, near the top, to 1.300, near the bottom. With the battery fully charged the hydrometer will sink only to the point marked 1.300, or somewhere near that point; but with a discharged battery whose electrolyte is mostly water the hydrometer will sink to the 1.100 mark. Different degrees of charge are indicated by the hydrometer's sinking to points on the scale intermediate between the 1.100 and the 1.300 marks. The point indicated at the surface of the liquid is the specific gravity of the electrolyte. If the scale were long enough and the instrument placed in pure water, it would sink to the point marked 1.000, which is the basis of the scale. If the instrument were then placed in the kind of pure sulphuric acid used in batteries it would sink to about 1.835, which is the specific gravity of the acid generally used.

The hydrometer itself is usually carried in a larger tube with a small nozzle at its lower end that may be inserted into the cells, and with a bulb at the upper end so that some of the electrolyte may be drawn from each of the cells for purposes of test. In the top of each cell of every battery will be seen a small plug. This plug may be unscrewed or released from its lock and will leave an opening exposed that passes into the interior of the cell and through which the electrolyte may be seen, or the tops of the plates if the liquid is low enough. With the plugs removed, the hydrometer syringe, as the tube and bulb is called, may be inserted into the cell, and when the bulb is squeezed and allowed to expand some of the liquid will be drawn up into the tube and the hydrometer

will float in this liquid. (See Figure 40.) After all pressure has been released from the bulb the specific gravity of that liquid may be noted on the hydrometer scale at the point where the instrument rises above the surface of the electrolyte. The gravity

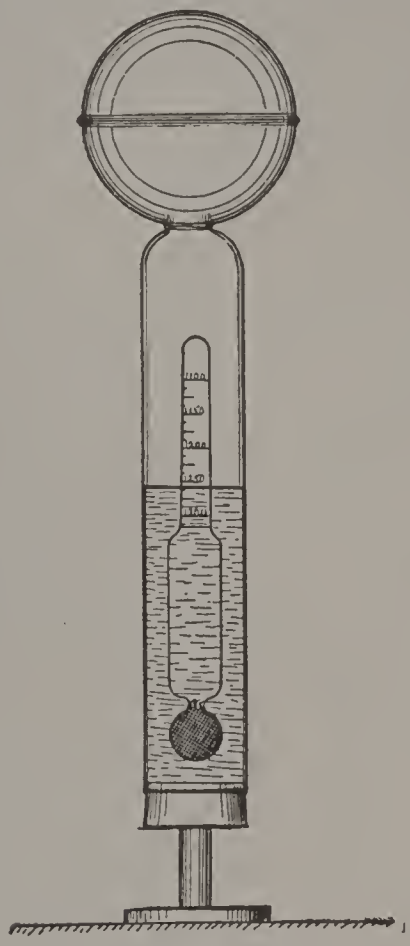


Figure 40.—Hydrometer Floating in Liquid Drawn Up Into Syringe.

should then be noted and the liquid carefully returned to the same cell from which it was drawn. The same method should be used to find the specific gravity of each cell.

If this gravity is between 1.250 and 1.310, the cell is well charged. If the gravity is between 1.200 and 1.250, the cell is at least half, but not fully, charged. Gravity between 1.150 and 1.200 indicates that the

cell is nearly discharged, while gravity of 1.150 or below means that the cell is discharged to a point at which no further discharge should be allowed. The gravity is often mentioned in "points," the difference between 1.200 and 1.250 being 50 points.

The specific gravity should not be tested until after the battery has been charged, should the water be found so low that it is necessary to add more to bring the liquid above the plates. If the battery is in good condition, the gravity will be within twenty-five points of the same in all cells. If there is a greater difference than this it usually indicates trouble in the cell or cells that are low. When, near the end of a charge, the specific gravity of the liquid in a cell does not show any increase for two hours or for three readings taken one hour apart, the cell is fully charged. At this time bubbles of gas should be rising through the electrolyte and showing freely on the surface.

BATTERY CARE

It is very essential that the storage battery have certain attention at regular intervals. The most important item in the care of a battery is that of adding pure water to each cell at least once each week during warm weather and at least every second week in cold weather while the car is in use. The water is added through the holes left with the vent plugs removed and may be easily handled by using the hydrometer syringe. A sufficient quantity of water should be placed in each cell to bring the surface of the liquid from one-quarter to one-half inch above the tops of the plates, this point being indicated in most cases by a rim that can easily be seen at the bottom of the hole with the plug removed.

The water used for this purpose must be distilled or else perfectly clean rain water. Tap water or water that has been kept in metal containers must never be used. Some city waters may be used, but it will always be necessary to make an analysis before their safety can be determined. Except when some of the electrolyte has been spilled from one of the cells, nothing but pure water should ever be added. In no case should undiluted sulphuric acid be used. If it is known that a part of the electrolyte has been lost through other means than by evaporation and the slight spray from gassing, the level may be brought up in the low cell by testing the gravity in the adjoining cells and then making enough electrolyte of this gravity to bring the level in the low cell to the required point.

Electrolyte is made by slowly pouring chemically pure sulphuric acid into distilled water until a mixture of the desired gravity is reached. Two and one-half parts of water to one of acid will make a mixture of about 1.300 specific gravity. Lower gravity is secured by adding more water. The mixture must be allowed to cool before it is added to the cell. If the water is poured into the acid, a violent action and throwing of liquid will take place.

The specific gravity of each cell of the battery should be taken at regular intervals, and if the whole battery is getting lower the fault should be looked for without delay. If one cell becomes lower, but the others remain normal, trouble in that cell is indicated. Care should be used when testing not to spill electrolyte on top of the battery, as it will cause corrosion at the terminals and partial short-circuiting of the cells. If it is found that one cell always takes more

water than others, it is probable that the jar for that cell has become broken. The level of the liquid in the cells should not be above a point one-quarter to half an inch above the tops of the plates, because during charge the gassing that occurs will cause the electrolyte to overflow and cause damage outside of the cells.

At the time of testing or adding water to the battery, the terminals should be carefully examined for looseness or breakage, either at the connecting bars between the cells or at screwed or tapered connectors. No copper wires should ever be attached at the lead battery posts, as they will soon be eaten away by the action of the acid. Should the connections be found covered with corrosion or verdigris, they should be washed with ammonia water, and in any case should be covered with a coat of vaseline to prevent such action by the acid.

The battery must be firmly secured in its box so that movement from the motion of the car is impossible. Wood cleats should be placed under the battery and fastened into the bottom of the box. The space all around the battery and on top should be free and open for the circulation of air. The best method of holding the battery is by using hooked bolts that catch on the battery handles and screw down tight. If the battery case is wet or if the inside of the battery box is wet, the moisture should be wiped away with a cloth slightly wet with ammonia water.

It is, of course, essential that the electrical conditions of charge and discharge be correct for the battery. These points are taken up in other parts of this book, but it should be noted that the dynamo should give such an output at fifteen miles an hour

car speed that the battery is not being discharged with all lamps turned on. It should also be remembered that the demands on the system and on the battery are much greater in winter than in summer. The efficiency of the battery is much lower when cold than when warm, and the dynamo does not give an output as great as would be required for the extra lamp load imposed by the greater number of dark hours, and also by starting a cold engine under winter conditions. Therefore, the battery should have the very best of care during cold weather. Lamps should be used as economically as possible, and, if convenient, lower candlepower bulbs should be substituted in the lamps. The engine should be started by hand for the first time on cold mornings, and at all times the carburetor and ignition should be in such adjustment and condition that but a very few seconds' cranking with the motor will suffice to start the engine. Care of this kind will do more than anything else to insure satisfactory operation of the whole electrical system, because nothing else can do its work unless the battery is in good order and properly charged.

CHAPTER IV

LAMPS AND WIRING

One of the principal purposes of the whole electrical system is to furnish light, and the subject of lamps and their connections is an important one. The lighting parts that are most directly concerned are the bulbs and reflectors in the lamps, the wiring with its insulation and supports, the switches for turning the lamps on and off, and, in some cases, the protective devices, such as fuses and circuit breakers.

THE LAMPS

Bulbs.—A bulb is composed of a filament enclosed in a glass housing from which the air has been almost completely exhausted, and this glass part is carried on the metal base (Figure 41). Two kinds of filament are in use, tungsten and carbon, and two kinds of bulbs, one in which the exhausted air is not replaced, and another in which the air is replaced with nitrogen gas. The first kind of bulb is known as the vacuum type, the second is called a nitrogen bulb.

Tungsten filaments should be used exclusively because of their greater efficiency as compared with carbon. Depending on the candlepower, the tungsten filament will require from 0.95 watts for each candlepower up to 1.25, while the carbon bulb will take on an average of 2.5 watts for each candlepower of light. It is, therefore, poor economy to use carbon filament

bulbs for any purpose. In making lamp calculations the following data may be used:

Bulbs up to 4 c.p....1.2 watts per candlepower
6 c.p. to 10 c.p.....1.0 watts per candlepower
12 c.p. and above.... .95 watts per candlepower

Bulbs operating at their normal voltage will require an amperage sufficient to allow the specified consump-

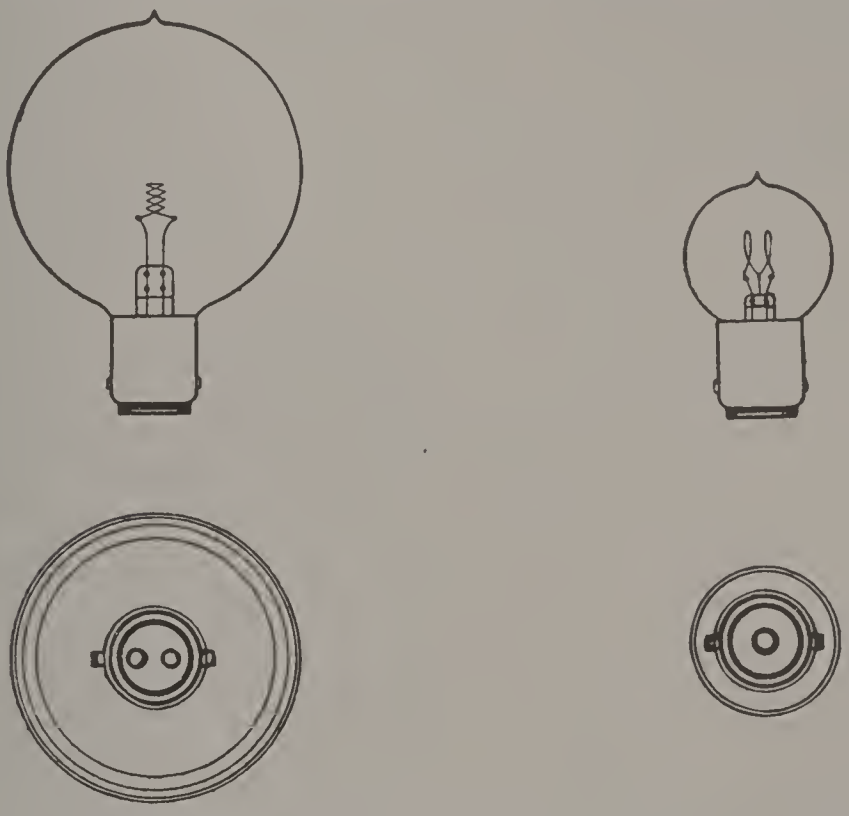


Figure 41.—Double-Contact and Single-Contact Lamp Bases.

tion in watts. This will cause the bulb to give its full candlepower, and its useful life may be expected to reach from 200 to 300 hours of burning. If the voltage is less than normal, the bulb will not require its rated flow in amperes, and under these conditions the candlepower will be lower and the life longer.

Bulbs in common use range in voltage from 3 or 3½ up to 21, depending on the number of cells in

the battery with which they are used and their connection with each other. It is customary to use bulbs of a voltage one-sixth above what would be required on a basis of exactly two volts for each cell of the battery. Thus, with a three-cell battery, seven-volt bulbs will be used in place of six; with a twelve-volt battery, fourteen-volt bulbs will be used, while with an eighteen-volt battery, twenty-one-volt bulbs will be found. The three-volt bulbs are used in pairs on a six-volt battery, the two three-volt bulbs using the six volts of the battery just as one six-volt bulb would do.

Five bulb sizes are in use. The bulb size refers to the diameter through the glass part, and does not vary exactly according to the candlepower. Two, four and sometimes six candlepower bulbs are made of three-quarter inch diameter. Four, six and sometimes eight candlepower bulbs are one inch or one and one-quarter inches. Bulbs of larger candlepowers are made either one and one-half or two and one-sixteenth inches in diameter. In replacing old or broken bulbs with new ones, the replacement should be made with a bulb of the same diameter as the one removed, otherwise it will be necessary to refocus the lamp, and if too great a change is made in the size the refocusing cannot be done properly.

Bulb Bases and Sockets.—Four types of bulb base are in use; two, of the familiar screw type, are seldom found except in interior body work, while the other two, of the bayonet type, are in common use for all purposes. The bayonet type is often called the Ediswan socket, and makes use of a spring locking device that holds the bulb firmly in place against jarring and consequent loosening. (See Figure 9.)

The base for this type is cylindrical and carries two small projecting pins on the sides and directly opposite each other. The socket into which the base fits is also cylindrical, and of such proportions as to make a rather loose fit. Two slots are cut along the sides of the socket, and when the bulb base is placed in position, the projecting pins slide into these slots. At the bottom, the slots end in a small upturned notch so that the base pins will fit into the notches when the bulb is given a part of a turn. In the bottom of the socket are springs that press against the inner end of the base and keep the pins in place in the notches.

One kind of bayonet base carries a single electrical contact in the center of the bottom of the base, this contact coming against a contact spring or plunger in the socket when the bulb is in place. The current for the lamp is carried through the contact for one side of the circuit, while the connection for the other side of the circuit is completed through the metal of the base cylinder where it comes in contact with the metal of the socket. This is called a single contact base, and was primarily designed for use with the one-wire or grounded system of wiring in which the shell of the socket is attached to the metal of the car to carry the current for one side of the circuit.

Another kind of bayonet base has two contact points on the bottom of the bulb, both being insulated from the metal of the socket and from each other. The current for the lamp is carried in through one contact and out through the other, and there are two springs or plungers in the socket that make connection with the base contacts when the bulb is in place. This is called the double-contact base, and is used with the two-wire, or insulated return method of car wiring,

in which both sides of the circuit are carried by insulated wire.

One of the screw types is called the candelabra base, and the other one, which is of smaller size, is called the miniature base. Their construction is similar to that used for house lighting work, a single contact carried in the center of the bottom of the base making connection with a spring in the bottom of the socket. The other side of the circuit is completed through the shell of the socket and of the base.

Lamp Care.—The light from the bulbs is directed toward the road by means of silver plated reflectors of parabolic shape or by reflectors made from silvered glass like a mirror. The glass reflectors are not found as commonly as the silvered metal ones, but give satisfactory service when used.

In order to reach the interior of the lamp for bulb renewal, cleaning or focusing, it is necessary to remove or swing to one side the glass cover placed over the front of the lamp. This cover may be held in place by hinges, although plain hinges are seldom used because the lamp should never be opened except when really necessary, and because of the danger that the bulbs will be taken out if left too easily accessible. Lamps are often made with pinned hinge joints on both sides, and it is then necessary to withdraw either one of the pins to allow the other side to act as a hinge.

The lamp covers or glasses are often held in place by screws and in some cases the screw-heads are made so that it is necessary to use a peculiar form of wrench that is furnished with the tool equipment of the car. A type of lamp in rather common use holds the fronts in place by means of a spring lock, and with the cover

in position nothing about the outside of the lamp gives any indication as to the method of fastening. This type is handled by pressing in on the rim of the cover and at the same time turning it to the left, when the whole front of the lamp will come off. Great care should be used to prevent dirt or moisture from touching the reflector while the cover is removed.

Should the reflectors become dirty or tarnished, they may be carefully cleaned and brightened, although the surface of the reflector will be somewhat

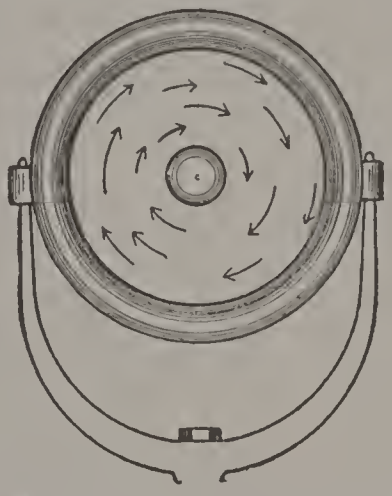


Figure 42.—Method of Cleaning Lamp Reflectors.

damaged every time it is touched, no matter how careful the work is done. Dust may be removed from the reflectors by blowing it out or, if it does not yield to this treatment, a stream of clean cold water at very low pressure may be used. If water is used the reflectors must be allowed to dry by the air alone, and must not be wiped off.

For cleaning the silvered surface no liquid except alcohol is ever used. This is applied with a clean, soft chamois skin. The chamois must be held so that there are no wrinkles, and the reflector is then wiped over the whole surface by using a rotary motion (Figure 42), starting at the bulb socket and

gradually working out toward the front of the lamp. The cleaning is sometimes done by wiping from front to back, but in either case the pressure should be very light and even. Rubbing back and forth will surely scratch the surface of the reflector.

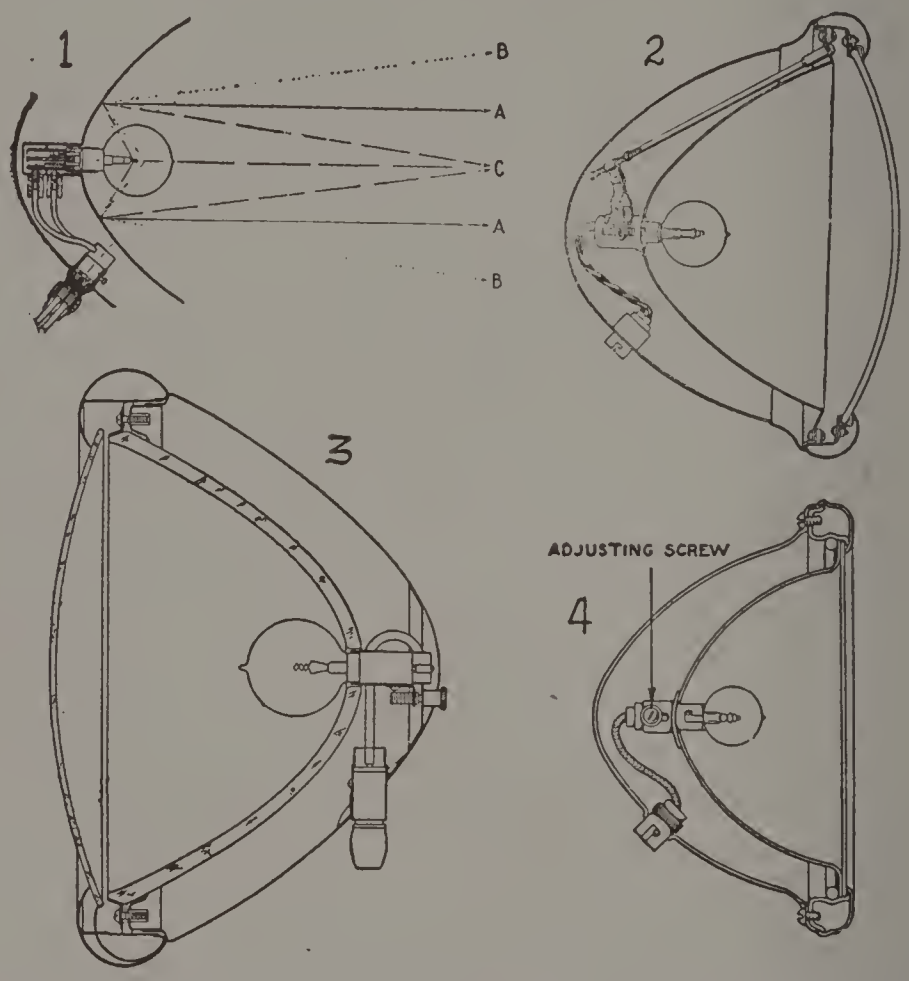


Figure 43.—Lamp Focusing Methods. 1—Light Rays Follow Lines *A* with Proper Focus; with Improper Adjustment They Follow Lines *B* or *C*. 2—Focusing Screw at Upper Front Edge of Reflector. 3—Focusing Screw at Rear of Lamp Case. 4—Adjusting Screw in Lamp Socket.

If the silvered surface is tarnished it may be polished by moistening the chamois with alcohol and then applying a small quantity of jeweler's rouge. The wiping should then be done in the same way as for cleaning. After the coating of oxide has been re-

moved, the polish is completed with more rouge placed on a dry chamois skin.

In order that the lamps may be used to the best advantage, the bulbs must be properly focused and the lamps must be in such a position on their brackets that the rays of light are thrown on the road at the proper point. It will generally be best to get the bulbs in approximately proper focus and then place the lamps in proper alignment.

The bulbs are focused by moving them forward or back in the case so that their filaments will come into a different relation to the curved surface of the reflector. (See Figure 43.) Many lamps are made so that the bulb position may be changed by turning a small screwhead or nut that will be exposed when the front of the lamp is out of the way. The focusing screw is usually in the center of the upper edge of the rim, and by turning it one way or the other, the bulb is moved forward and back. Bulbs are also held in a socket that may be slid bodily in or out of the reflector by first turning it slightly. When the bulb and socket have been moved to the desired position, the socket will lock in place when released. Other lamps hold the socket in a cylindrical casing and lock it in place with a clamp or setscrew. This screw can be reached from the rear side of the reflector, and with it loosened, the socket may be pushed back and forth.

One lamp should be focused at a time. This may be done by turning the current off from one of them or by covering one with a thick cloth or coat. The focusing must be done in a dark room or on a dark road, preferably on the road. The car should be placed so that no street lights are near enough to cast a light near the car, because they will affect the

adjustment. The bulb should be moved back and forth until the light on the road is clean and free from rings or black spots. If the work is done in a room, the light may be directed against a wall and the bulb moved until a clean and clear ring of light is thrown straight ahead. It will always be best to drive the car on the road before deciding that the adjustments are correct. It will often be found that focusing which is apparently right with the car standing still will not be the best that may be secured for driving.

After each of the lamps has been focused as described, the fronts should be replaced and the lamp casings moved on their brackets, or the brackets themselves moved so that the light from each lamp strikes the road at the point desired by the driver. The best method of changing the lamp position will be apparent upon examination. Some cars are provided with adjustments for this purpose and others have no means except to bend the brackets.

WIRING

This subject immediately suggests the two principal systems that are used for carrying the positive and negative sides of the circuits, that is, the one-wire, or grounded return, method, and the two-wire, or insulated return, method. The wiring applies as much to the charging system as to the lighting, and the information that follows will take both systems into account.

One-Wire System.—This construction makes use of the fact that the metal of which the chassis parts are made is an excellent conductor, and because of the large sectional areas in use as compared to the sizes of wire, a conductor of very low electrical resistance.

In place of the older method of carrying both sides of the circuits through copper wires insulated from metal parts of the car, the one-wire system attaches one side of the battery, one side of the lamps and one side of each of the other electrical units included, to the frame, or to other metal parts of the car that are in electrical contact with the frame. (See Figure 44.) From the remaining side of the battery wires are run through the switches and other connecting parts to the lamps and whatever other units are included in the one-wire system. Any part

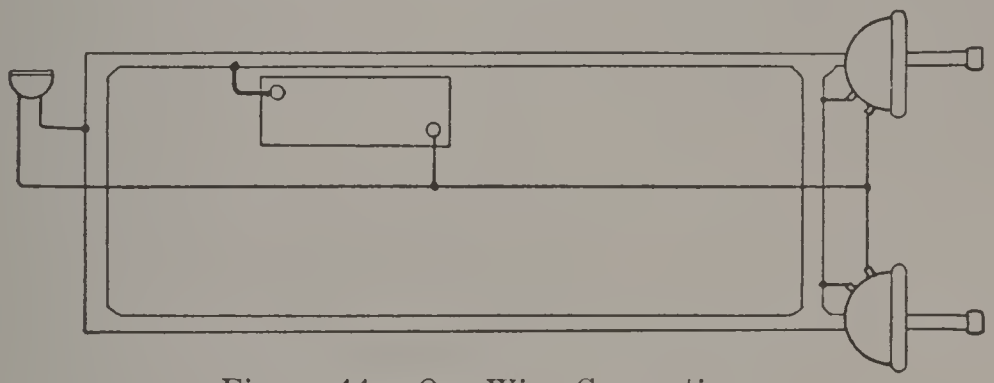


Figure 44.—One-Wire Connections.

that is thus attached to the metal of the car parts is said to be grounded, and this system is oftentimes called the ground return system.

Theoretically it would be possible to eliminate one-half of the wire that would be required with a two-wire system, but this is not true in practice, because it is not possible to place the battery, dynamo and other units in such a way that they may always be attached directly to the metal work, or to "ground." This is especially true of body lights and of side and dash lamps that are carried on wooden parts of the car. The saving from the standpoint of wire used is in practice between one-third and one-half, the exact amount depending on the design and mountings used.

The principal advantage of the one-wire system, outside of the evident advantage of saving in wire, is the greater ease of providing heavier insulation. It will be realized that, in a lamp socket and bulb base, for instance, the room that may be utilized is quite limited, and if but one conductor must be insulated, the covering and protection for this one side of the circuit may be made heavier than were it necessary to handle two insulated leads for each lamp.

The same advantage applies in a similar way to the other units, and because of the saving in material

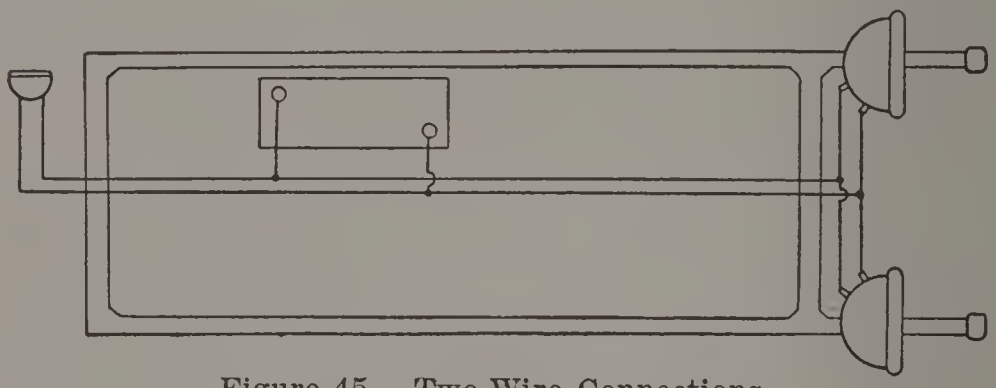


Figure 45.—Two-Wire Connections.

and the greater ease of manufacture and installation, the one-wire system has gained steadily at the expense of the two-wire system since its first adoption.

Care must be used with this system of wiring to see that the connections of the copper wires from the various units are securely fastened to the metal of the car and that the contact surfaces are perfectly clean and protected from the action of air and moisture.

Two-Wire System.—This method of wiring does not make use of the metal work of the car as a conductor, both sides of the circuit being carried by insulated copper cables at all points (Figure 45). The most apparent advantage of this method is in the

lessened danger of accidental short circuits from broken insulation. With both positive and negative conductors insulated it would be necessary to break through the insulation on both sides before any leakage of current could take place. Even though the positive wires were bared, no current could flow from positive to negative sides of the battery unless the negative lines were also bared at a point that would allow contact between positive and negative. Likewise, the negative cables might be stripped of their insulation at one or more points without leakage occurring unless the positives were also stripped at the points that would touch the negatives.

With the one-wire system either the positive or negative side, depending on which one is grounded, will always be without insulation, and a failure of the insulation on the other side of the circuit at any point where the cable can come into contact with the metal parts of the car will result in a short circuit. This may be guarded against to a certain extent by the heavier insulation possible with the one-wire system.

Because of the possibility of short circuits with the one-wire method, it is customary to use fuses that will burn out or circuit breakers that will open with an abnormal flow of current through the wires. By thus breaking the circuit in trouble, the danger of completely discharging the battery is eliminated. With the two-wire system fuses and circuit breakers are not so commonly used, although their adoption or omission depends entirely on the ideas of the designer.

Another advantage of the two-wire system is found in the absence of connections between copper con-

ductors and the steel or aluminum of the metal parts of the car. This form of joint is not as easy to make and is not of such low resistance as one between copper and copper. Any joint between two different metals is subject to an electrical action that will result in corrosion and high resistance unless the joint is properly protected. The grounding connections between the lamps and their brackets and between the

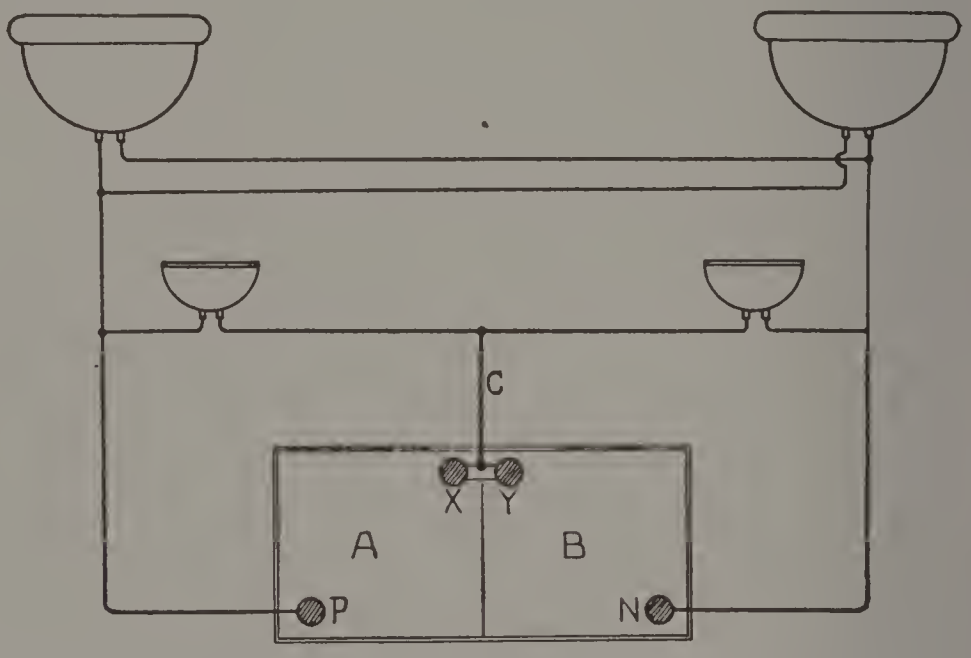


Figure 46.—Three-Wire System with Evenly Divided Battery.

electrical parts mounted on the engine and the metal of the engine must be well made and carefully watched to avoid looseness and dirty contacts with the one-wire system, while the two-wire method requires only that the joints be clean and tight between surfaces that are both copper.

Three-Wire System.—This class of wiring designates a method by which two different voltages may be secured on two different circuits with the use of but three wires for both circuits in place of four, as

would ordinarily be required. It may be used with either the grounded or insulated return wires, inasmuch as it really means three conductors, which may be of wire or of the metal of the car parts.

The connections for one kind of three-wire system are shown in Figure 46. The battery is composed of two separate sections, *A* and *B*, which, for purposes of illustration, may be considered as of six volts each. The two sections are connected at their terminals, *X* and *Y*, *X* being negative and *Y* positive. The remaining terminals are shown at *P* and *N*, *P* being positive and *N* negative. Between the terminals *P* and *N* twelve volts may be secured, inasmuch as both sections are working together and adding their pressures. The head lamps are connected so that each bulb is attached to battery terminal *P* and to *N*, and they will therefore operate at twelve volts pressure.

The side lamps are connected in such a way that the left-hand lamp is attached between positive terminal *P* and negative terminal *X*, using one section of the battery and six volts' pressure. The right-hand side lamp is attached between the negative terminal *N* and the positive terminal *Y* on the other section of the battery, and also at six volts pressure. The terminal formed by joining *X* and *Y* is called the neutral terminal, and the wire *C* is called the neutral wire.

It will be seen that the removal of the wire *C* would leave the two side lamps in series with each other, so that all the current passing through one of them would also have to pass through the other. With the wire *C* removed, the two lamps would be connected in series between the battery terminals *P* and *N*, and would receive twelve volts. Two six-volt lamps

will operate on a twelve-volt circuit when connected in series, and this rule holds true for any combination of voltages in which the battery or circuit voltage is equal to the number of lamps multiplied by the voltage of each lamp. The lamps must all be of the same voltage, and this method would not always operate with one six-volt and one twelve-volt lamp on an eighteen-volt circuit.

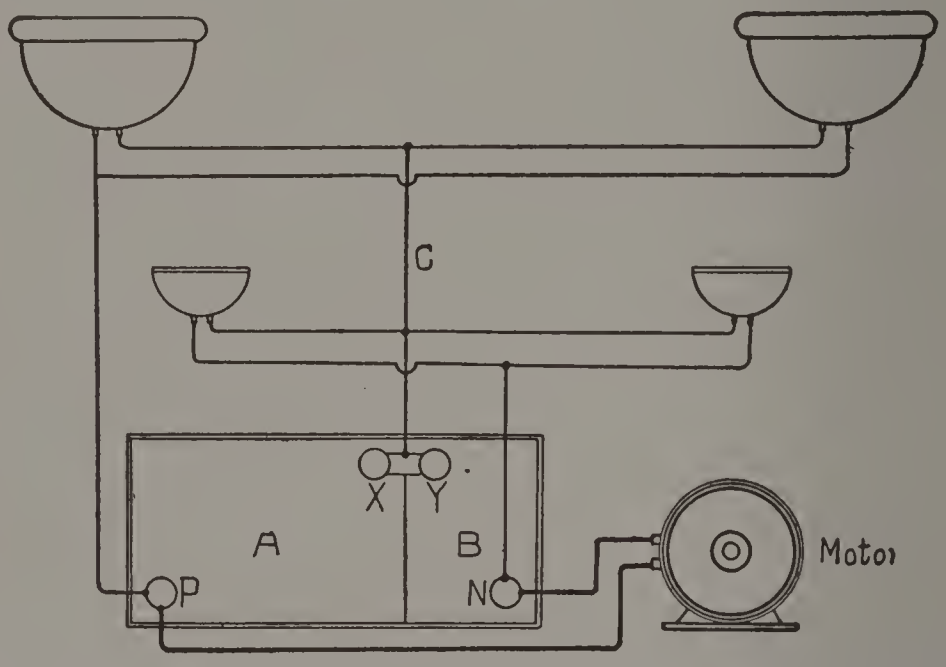


Figure 47.—Three-Wire System with Two-Lamp Voltages and Higher Voltage for Starting Motor.

The advantage of the neutral wire *C*, in this case, would be that either one of the side lamps could be operated independently of the other by allowing the neutral wire to carry the side lamp current. With both lamps turned on, the neutral wire is dead, and the current flows from battery terminal *P* to terminal *N*.

Another three-wire arrangement is shown in Figure 47. In this case the battery is divided into two sections of unequal size, section *A* being six cells of

twelve volts, and section *B* of three cells and six volts. The sections are connected with each other between terminals *X* and *Y*. This arrangement allows of three different voltages. The starting motor is connected between the terminals *P* and *N*, and receives the full voltage of both sections, which will be eighteen. The head lamps are connected between the positive terminal *P* and the negative terminal *X*, and therefore operate with twelve volts from the battery section *A*. The side lamps are connected between the negative terminal *N* and the positive terminal *Y*, and therefore operate at six volts on the battery section *B*. The wire *C* is in this case neutral and acts for either the side or head lamp circuit. Were the wire *C* to be removed from Figure 47, it would leave the twelve-volt head lamps in series with the six-volt side lamps on an eighteen-volt battery. As stated before, this should not be done, because, except under one condition, either the head lamps or the side lamps would not burn. The one condition under which both sets would burn with the neutral wire removed is with both sets of such candlepower that they would require exactly the same amperage to light them. With lamps in series, the flow or amperage is the same through all parts of the circuit, and the set that takes the least amperage will govern the flow through the circuit, with the result that the lamps that require a greater flow will not light up at all, or but dimly.

Wires.—The wires may be considered as consisting of the copper which forms the conductor for the current, of the insulation covering the conductor, and of the terminal connections that serve to make the necessary attachments between the various wires and between the wires and the electrical units on the car.

Of the three parts, the last will be found most important from the standpoint of upkeep. The greatest trouble is experienced in making and keeping the terminal connections tight and clean at all times. Unfortunately it is not possible to make permanent connections, because of the necessity that may arise for removing some of the wiring or some of the instruments. It will, therefore, be necessary to use the greatest care at this point if trouble is to be avoided.

The size of conductor that should be used at any particular point in the installation depends on the amperage and voltage that is to be carried and on the length that the current must be taken between the units. Conductors are usually measured by wire gauge sizes, in which the larger numbers indicate the small sizes of wire, while low numbers indicate large sizes of wire. Gauge sizes (Brown & Sharpe standard) are found from No. 16 (about one-twentieth inch in diameter) to No. 00 (nearly three-eighths inch in diameter). Sizes from No. 3 up to No. 00 are used for the starting circuits, while sizes from No. 8 to No. 16 are for lighting and charging circuits. Should the wire size be too small for the work it is called upon to do, the resistance will be so great as to cause an abnormal drop in voltage and improper operation of the units supplied by the defective circuit.

The insulation of the wire is oftentimes called upon to do double duty in giving protection against leakage of the current, and also in protecting the conductor against mechanical injury. Electrical protection is usually cared for by various compounds of rubber that surround the conductor with a protective coating of sufficient thickness to resist the voltage in

use plus a liberal margin for safety. Various means are used to give mechanical protection, the commonest being a covering of fabric woven or braided over the electrical insulation of the wire. In many installations the mechanical protection is given by covering the wire with a flexible housing of braided brass or very thin steel. This type is called armored cable, and gives excellent results in use.

The wiring should be firmly fastened to the parts of the car near which it runs, and these fastenings should be made with screwed joints of some form. The wires should never be fastened in such a way that the covering will come into contact with corners or sharp edges of metal, because the final result will be breakage or short circuits. In case it is necessary to run the wiring into positions where it will be exposed to the possible action of grease, oil or water, it should have a weatherproof coating of some form. If armored cable is not used it is general practice to use metal tubing of flexible construction, or else to use conduit. Should neither of these protecting coverings be supplied, the needed protection may be given by covering the exposed portion of the wiring with ordinary circular loom, such as is used in stationary electrical construction.

No wire should be used that is not designed for starting, lighting or ignition work. This means that the conductor must be composed of a cable made up from a large number of fine wire strands and known as flexible or stranded cable. The insulation must be designed for this class of work, and under no conditions is it permissible to use substitutes like flexible lamp cord, such as is found in house wiring.

All wire ends should be fitted with metal terminals

(Figure 48) of special form, designed to make a good electrical and mechanical connection with the various units. These terminals should always be soldered to the ends of the wire so that there is no chance of corrosion or looseness. In case it is necessary to attach a wire and no terminal can be fitted, the work may be done by baring the end for a short distance and, after bending the end into a loop, dipping it into solder so that it is made solid enough to prevent loose strands from forming. The loop should then be placed on its connection in such position that it wraps around in a right-hand direction, and so that tightening of the

Figure 48.—Wire Terminals.

screws will tend to coil the wire closer around the terminal post in place of unwrapping it.

After wiring has been attached to the terminal posts, the fastening screws should be made tight and should preferably be locked in position with wire or by soldering. While this method makes it harder to remove the parts, it also prevents the commonest of all troubles, looseness.

SWITCHES

The amperage or current that is carried by the circuits of the automobile lighting system is considerably greater than that carried in the ordinary house lighting system. The amount of light in candlepower may be no greater or it may be about the same. This would mean that the power in watts would be about

the same, and because of the low voltages in use with car lighting systems, the amperage must be correspondingly higher. The contact surfaces of lighting switches for use on cars must be made large and of material that will stand the sparks that are formed when the circuits are broken.

Many types of separate lighting switches are in common use. One of these types carries two small push-buttons on its face-plate, one button serving to close the circuit and the other to open it. They are mounted at opposite ends of a pivoted arm so that pushing one of them in will cause the other one to come out. The contacts are actuated by spring-operated arms so that the circuit is broken quickly enough to prevent excessive arcing. Another type very similar in construction makes use of but one button, this usually being pulled out to close the circuit and turn on the lights and pushed in to turn them off. One switch is provided for each circuit that is to be controlled, and the switches are usually assembled with the proper number attached to one face-plate that appears within reach of the driver.

A third type is that known as the rotary snap switch (Figure 49). This is built on the same principle as the switches in common use for house lighting, with which the switch button is always turned to the right to turn the lamps off if they are burning and to turn them on if they are unlighted. These switches for automobile work are made so that the several combinations of lights are given by successive quarter turns or sixth turns of the button. A combination in common use for the four quarters would be as follows: All Off. Head Lights Dim, Tail Light Bright. All Lights Bright. Side Lights and

Tail Light On. The next quarter would then bring the switch back to the "All Off" position.

Many combination switches are in use that care for the lighting, starting and ignition circuits by bringing two of them or all three to the one-switch unit. The combination switch that serves for lighting and ignition is in most common use, this type usually being fitted with separate buttons or levers for the two functions. This makes it in reality two switches of

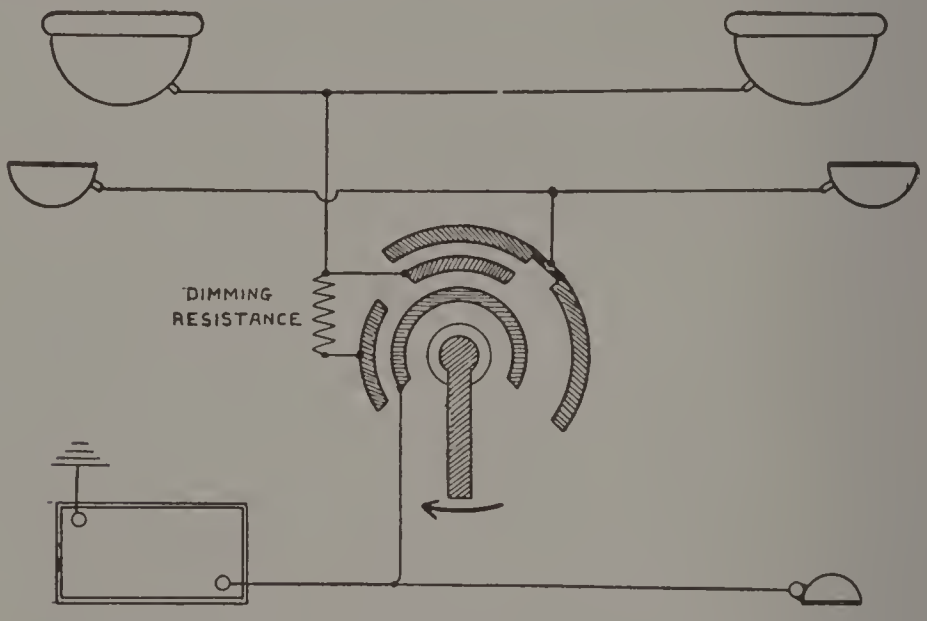


Figure 49.—Rotary Lighting Switch Construction.

any suitable form carried in one housing. Switches are also in use that have but one lever or button for both lighting and ignition. With the switch button in place, the ignition is turned on, and with the button moved into various positions the different lighting combinations are secured. Removal of the button with any lighting combination in use will then stop the ignition, but will allow the lights to remain lighted as with the button in place.

Combined starting and ignition switches are in general use with motor-dynamos that do not make use of

an automatic cut-out. (See Figures 59 and 60.) These switches usually have three positions, although they are also made with but two changes, "On" and "Off." With the three-position switch the points are marked "Off," "Neutral" or "Idle," and "Start" or "Run." In the "Off" position the ignition is inoperative and the motor-dynamo is disconnected from the battery. In the "Start," or "Run," position, the ignition is turned on and the battery current is allowed to flow to the motor-dynamo, making it act as a starting motor. If the switch is left in this position the motor-dynamo will act as a dynamo when the engine speed is sufficiently high. In the "Neutral," or "Idle," position, the ignition is turned on, but the motor-dynamo is disconnected from the battery, so that no starting motor action will take place. Some switches have a "Neutral" position in which starting motor action can take place, but arranged in such a way that the field circuit for the dynamo is open and the unit cannot charge the battery. This last arrangement is designed to prevent excessive battery charge on long runs, such as in touring.

Combined starting, lighting and ignition switches are also made in various forms. They may be simply a collection of the separate switch units in one case, or they may be designed to produce starting, lighting or ignition by movement of one lever or button in different directions. Such switches are marked on the face-plate so that the operator need only follow the directions to secure the desired result.

FUSES

A fuse consists principally of a short length of wire of such a composition that it will carry a certain

amperage with very little resistance, but when this amperage is exceeded will rapidly rise in temperature to such a point that it will melt and thus break its connection in the circuit and prevent further flow of current. Fuses are used in either the lighting or charging circuit and oftentimes in both. The wire may or may not be enclosed inside of a small tube. When unenclosed they are called open-fuse links, or simply fuse wire. This form is not safe to use around a car because of the danger of fire from the exposed flash should the fuse burn out. Enclosed fuses are called cartridge fuses and may be surrounded with a tube of fibre or one of glass (Figure 50). With glass-

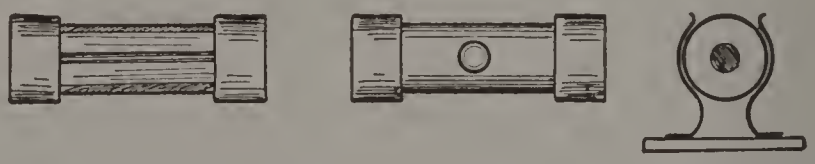


Figure 50.—Glass and Fibre-Bodied Cartridge Fuses.

enclosed fuses it is very easy to discover when one has been burned out by looking through the glass. With fibre covering, burning of the fuse causes a small blackened spot to appear at some point along the tube, usually at the center. Fuses may always be tested by attempting to pass current through them and at the same time through a lamp or meter of some kind. Failure to secure a flow indicates a blown fuse, and it will be necessary to replace that one with a new one. Their cost is so low that there is no economy in attempting to renew the fusible wire.

Fuses are always rated according to the amperage they will carry without burning out. The voltage need not be considered in their selection. The proper size to use will, of course, vary with the voltage and

candlepower of the lamps supplied or with the flow required through the charging circuit, field circuit or other path of current in which they are placed. In the absence of definite instructions the following sizes may be used. These are calculated for a six-volt system. Higher voltages will require a smaller amperage and fuses of lower rating.

Head lamps.....15-ampere
Side lamps only.....5- to 8-ampere
Tail and dash lamps.....5-ampere
All lamps.....20-ampere
Horn 15-ampere
Dynamo field fuses.....3- to 10-ampere
Charging circuit fuses .....20- to 45-ampere

A fuse should never be replaced with one of a larger size than that specified by the car or equipment manufacturer, and should never be replaced with wire or nails. Fuses are only used at points through which an excessive flow of current may occur, and which will cause more or less serious damage when it does occur. Replacement with such substitutes in the lamp lines may result in burning out all the bulbs affected; in the dynamo field circuits the result will be burned-out dynamo field windings, and in the charging circuits the result will probably be a ruined battery.

Cartridge fuses are held in spring clips at each end. These clips should be set so that they hold the fuse without looseness, and the contact surfaces between fuse and clip must be clean and bright. A particle of dust at this point will prevent any flow of current. Trouble may be experienced with the fastenings between fuse clips and their bases or between

the clip and the wire end to which it is attached. These points should be examined in case of an open circuit or a greatly diminished flow through a circuit in which fuses are used. In case the ends of a cartridge fuse or the surfaces of the fuse clips are found dirty or corroded they should be cleaned and brightened with sandpaper.

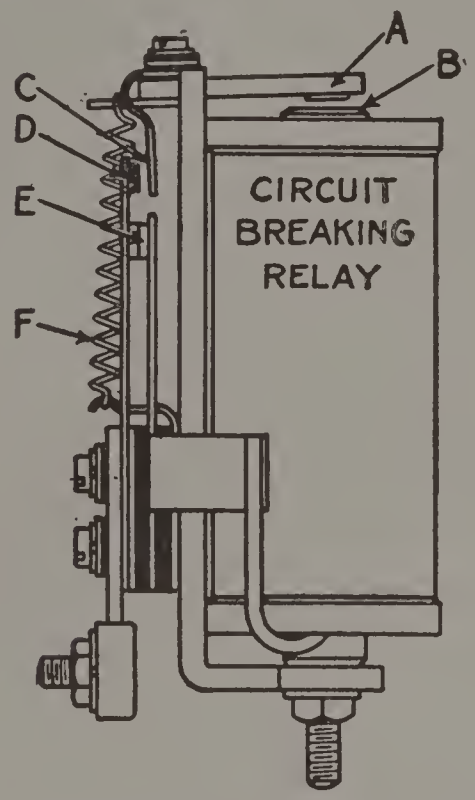


Figure 51.—Lighting System Circuit Breaker (Delco)
A—Magnet Armature.
B—End of Magnet Core.
C—Arm Attached to Armature.
D—Bumper on Movable Contact Arm.
E—Circuit Opening Contacts.
F—Spring.

CIRCUIT BREAKERS

The disadvantage in the use of fuses for protection is that spare ones of the right size must be at hand for purposes of replacement. Unless the right fuse can be easily obtained, it is a great temptation to replace it with a length of wire. To obviate this difficulty a magnetic circuit breaker is often used which rapidly opens and closes the circuit because of excessive amperage. (See Figure 51.) These circuit breakers consist of an electromagnet around which passes the current flowing in the circuit. Carried at a point near enough the magnet core to be influenced by it is a small armature, and to this armature is attached, either directly or by springs, one contact through which the current flows on its way around the magnet and through the circuit. A stationary contact is mounted so that

it touches the movable one, and as long as they remain together the current flow can continue.

Should the amperage passing around the magnet become too great for safety, the armature is attracted and the contacts are separated, because the magnetism produced will overcome the strength of the spring that normally holds the contacts together. The circuit breaker contacts may then remain apart or come together again, depending on the design. With no other parts than those described, the contacts will immediately come together after they once open, because the flow around the magnet is stopped when they separate. With no flow around the magnet the spring will again cause the circuit to close, and the action will be repeated rapidly, with a continuous clicking or buzzing noise, until the cause of the excessive flow is eliminated.

Other forms of circuit breakers are so constructed that the movable arm is caught and held by a latch so that the circuit is not again closed after once being opened. A handle or trigger is arranged so that the driver may release the latch and allow the breaker to return to its operative position. The adjustment of a circuit breaker spring should never be changed, because this would have the same effect as if fuses were replaced with others of higher capacity. The tension is just right for the current to be carried, and any increase will probably result in damage.

LAMP DIMMING

It is often desirable to reduce the amount of light or candlepower of the head lamps to prevent glare being thrown in the eyes of drivers of approaching cars. This dimming is required by law in many parts

of the country, and must be provided for in some way or other on all cars. The method that has been used for the longest time is that of providing additional lamp bulbs of smaller candlepower than those used for the large head lamps. These small bulbs are often called "dimmer" bulbs or "pilot" bulbs, and may be carried inside of the head lamp housing or in a small extension from some point on the lamp housing. Additional circuits are then arranged so that these small bulbs may be lighted when the large

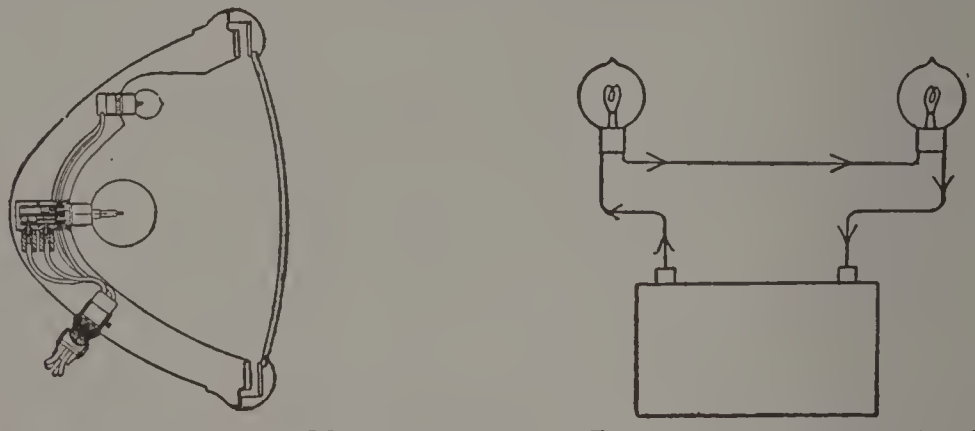


Figure 52.—Dimmer, Marker or Pilot Bulb in Headlamp (Left). Connections for Series System of Lamp Dimming (Right).

ones are turned off, and the light is thus cut down to the proper point.

Two other methods are in use, both of which cut down the flow of current through the large head-lamp bulbs to such an extent that the candlepower is much reduced. One method acts to place the two head-lamp bulbs in series with each other across the terminals of the battery (Figure 52). The resistance of the two lamps in series is twice as great as that of either one of them alone, and the flow of current through them is therefore reduced to half of its former value. Inasmuch as this means a reduction of the watts consumed in each lamp, the candlepower,

which depends on the watts, is reduced in proportion. Switches are arranged on the dash, or at any convenient point, so that the driver may place the lamps in parallel for bright lighting or in series for dimming. With the parallel connection each lamp bulb is connected directly to the two battery terminals so that each bulb receives the full battery voltage and takes its normal amperage. The arrangement is usually called series-parallel dimming.

Another method commonly used does not require the additional wiring called for by the series-parallel connection, and is, therefore, more easily applied.

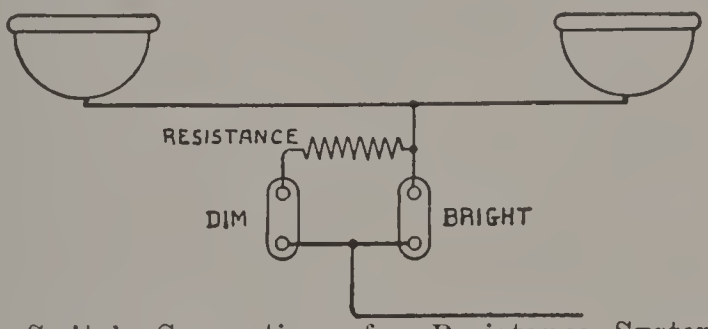


Figure 53.—Switch Connections for Resistance System of Lamp Dimming.

This method consists of a length of wire of high resistance that may be placed in the lamp circuit or withdrawn from the circuit, according to the driver's use of the switches. (See Figure 53.) The added resistance of this wire prevents the full amperage from reaching the lamp bulbs, and they burn less brilliantly. The extent of the dimming may be controlled by changing the length of resistance wire placed in the circuit, and with this form in use the lights may be made brighter by connecting two or more coils of the dimming resistance together with copper wire so that the lamp current will flow through the copper wire in place of passing through the resistance in the short-circuited coils.

CHAPTER V

CONTROLLING DEVICES

CUT-OUTS

All electrical equipments that include a dynamo for charging the battery must have a switch of some kind for disconnecting these two units from each other while the engine is idle or running at speeds so low that the voltage generated is not sufficient to cause charging to take place. But three principal types are in use, one being operated automatically by an electromagnet, another by a centrifugal weight, and the third being operated manually by the driver of the car. The switch of the third type is so connected that it will be operated with the starting switch or with the ignition switch, and thus the danger of leaving the charging circuit closed is avoided.

Electromagnetic Types.—The type of cut-out in most general use makes use of an electromagnet whose windings are connected between the dynamo brushes at all times. This magnet consists of a core of soft iron around which is wound a coil of many turns of fine wire. One end of this coil is connected electrically to one side of the dynamo and the other end of the fine wire coil is connected electrically to the other side of the dynamo. The magnet winding is, therefore, in shunt with the charging lines from the dynamo, and is called the shunt winding of the cut-out. The

proper operation of the cut-out depends on the action of a second coil of wire being added to the shunt coil. This second coil is so connected between the dynamo and the battery that all of the current passing through one side of the circuit from the dynamo during the time the cut-out contacts are closed will flow around this second coil. This winding is called the series coil of the cut-out, and the necessity for its presence will be considered after the action of the shunt winding is explained.

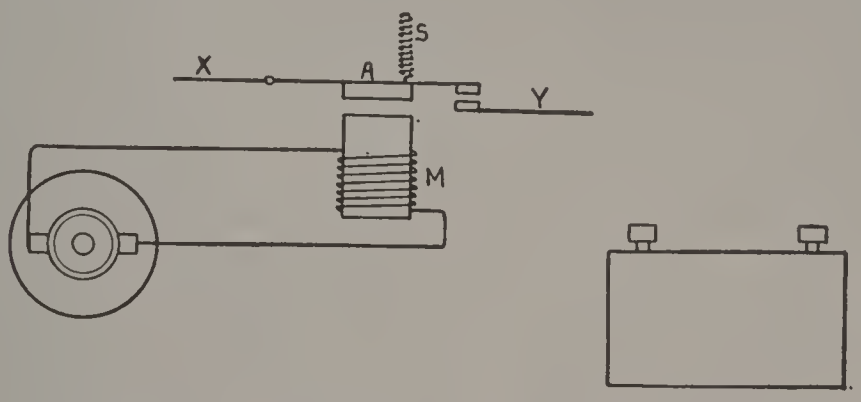


Figure 54.—Principle of the Magnetic Cut-Out.

Figure 54 illustrates the principle upon which the cut-out switch is closed. The winding of the magnet *M* is connected to the dynamo brushes as shown. The wire of which this winding is composed is so small and there is such a great length of it that the resistance through the coil is great enough to prevent more than a very slight flow of current passing through it. This avoids too great a loss of dynamo current through the cut-out itself. Mounted at some point on a hinged or spring arm above the core of the magnet is the magnet armature *A*, and when the magnetism in the cut-out magnet is great enough in strength, this armature will be attracted to the end of the magnet, overcoming the strength of the spring *S*. This will close the contacts

C, and a circuit completed through the wires *X* and *Y* will be closed by the movement of the cut-out armature.

With the dynamo idle there will be no pressure or voltage between its brushes and consequently no current will flow through the magnet winding. As soon as the dynamo starts to revolve some voltage will be generated, and this voltage will cause a flow of current through the cut-out shunt winding. The tension of the cut-out spring *S* is set at a point that holds the

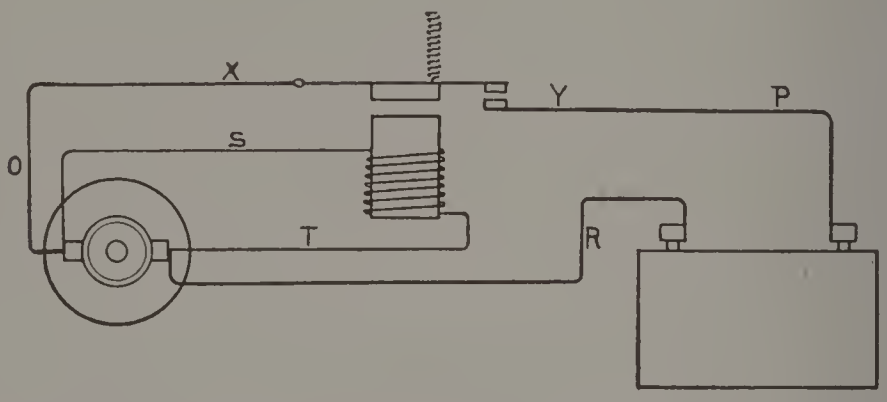


Figure 55.—Elementary Magnetic Cut-Out with Battery Connections.

armature *A* away from the magnet, and consequently holds the contacts *C* apart until the dynamo voltage has risen above the voltage of the battery to which the dynamo is attached. When the dynamo is operating at a speed high enough to cause a voltage in excess of that of the battery the contacts *C* will be brought together, and the circuit through wires *X* and *Y* will be completed.

In Figure 55 the dynamo is shown connected to the battery. The wire *O* has been connected from one dynamo brush to the wire *X* and the wire *P* has been connected from the wire *Y* to one terminal of the battery. The other dynamo brush is connected to the

remaining terminal of the battery through the wire *R*. Closing the contacts *C* will now connect the dynamo and battery, and inasmuch as the voltage of the dynamo is above that of the battery before the contacts close, the battery will be charged by current from the dynamo.

The connections and arrangement shown in Figure 55 would be satisfactory for closing the circuit between battery and dynamo, but would not open it properly in practice. Theoretically, the spring *S* would pull the contacts apart when the dynamo voltage falls to a point below that necessary to hold the contacts together. In actual operation the following action takes place: At the instant when the dynamo voltage becomes just equal to that of the battery as the dynamo speed falls, there will be no flow through the cut-out shunt coil. If this condition lasted for any appreciable time the contacts would open, but the falling dynamo speed immediately allows the voltage to become less than that of the battery, and before the contacts can open a flow of current starts from the battery to the dynamo through the closed contacts *C* and the wires *P*, *Y*, *X*, *O* and *R*, because the battery voltage is above that of the dynamo. A part of this flow will pass through the wires *S* and *T* and through the cut-out winding, thus holding the contacts together and allowing the battery to discharge through the dynamo. The cut-out remains closed at the comparatively low voltage of the battery because of the fact that it does not take as much magnet strength to hold the armature down as to draw it down across the air gap in the first place.

To overcome the fault just outlined, the connec-

tions shown in Figure 56 are used, this being the method actually used. The wire *S* has been combined with the wire *O* because both of them ran from the left-hand brush to the cut-out. The connection is completed from the end of *O* through the shunt coil of the cut-out just as it was completed from the end of *S* in Figure 55. The wires *T* and *R* have been combined into the wire *R* up to the cut-out and the current that has passed through the shunt coil of the cut-out returns to the dynamo through wire *R*. The

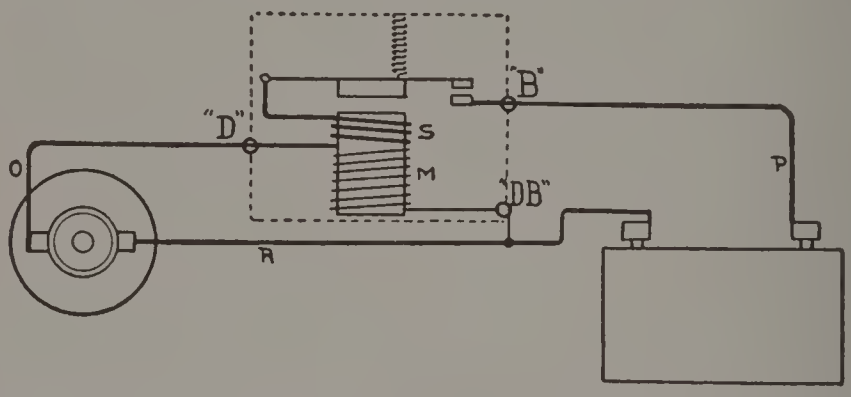


Figure 56.—Complete Connections for Electromagnetic Cut-Out.

shunt coil therefore closes the contacts just as it did before.

The current from the dynamo that passes to the battery through the closed contacts now enters the cut-out at the terminal marked *D*, and flows around the additional coil *S* on the cut-out magnet, then to the contacts and from the terminal *B* through the wire *P* to the battery. The flow through the two coils on the magnet is in the same direction and the strength of the magnet is increased after the contacts close. This effect is, however, incidental. The current that has passed through the battery then returns to the dynamo through the wire *R*, passing by the cut-out terminal *DB* and flowing through *R* with the

current that has passed through the shunt winding of the cut-out.

Now consider what happens when the dynamo voltage falls below that of the battery. Flow from the battery will take place just as soon as the dynamo voltage is low enough, but this flow must pass around the cut-out coil *S* in a direction opposite to its direction during charge. Part of this current will also pass through the lower shunt coil just as it did before, but the two coils now oppose each other because the flow of current is in different directions through them and the strength of the magnet will be completely destroyed as soon as the battery discharge through the coil *S* becomes great enough to overcome the strength of the coil *M*. At this time the contacts will be opened by the action of the spring and further discharge from the battery will be prevented. For the reason outlined, there should always be a slight discharge from the battery just before a cut-out of this type opens.

The second coil marked *S* and placed in series between dynamo and battery has another effect that is of importance. It will be realized that a cut-out having only the shunt coil would close and open at the same dynamo voltage. That is, if it closed against the spring tension at seven volts, it would reopen under the effect of the spring at seven volts. Should the car be driven at such a speed that exactly seven volts, or any other voltage corresponding to the spring tension, were to be generated, the cut-out would open and close continuously with damage to the contacts from the excessive hammering and sparking. With the series coil in use this action is prevented for the following reason: The cut-out closes under the action

of the shunt coil acting alone, because the series coil carries no current until the contacts close. This will make the closing point come exactly when the strength of the shunt coil alone is sufficient to overcome the spring tension. After the contacts are closed the series coil adds its strength to that of the shunt and the strength of the magnet is increased. If now the dynamo voltage falls to the point at which the cut-out closed, it will not reopen because the magnet is stronger than when closing took place. The contacts will therefore stay closed until the combined strength of both coils is as low as the strength of the shunt coil alone when closing took place. In practice the cut-out should stay closed until the speed of the car is about two miles per hour below the speed of closing, that is, the speed at which the contacts will reopen will be about two miles per hour less than the speed at which they close. This prevents rapid opening and closing at some critical speed of the dynamo and car.

As stated, the connections shown in Figure 56 are those generally used. Separately mounted cut-outs of this type usually have three terminals; one, *D*, leading to the dynamo only; another one, *B*, leading to the battery only; and the third one, *DB*, being attached to both dynamo and battery.

The most common practice places both windings on one core as shown and explained. In some cases, however, two separate magnets are used, one carrying the series coil and the other carrying the shunt winding. Other types use two cores with part of each coil on each of the cores. These two cores, with either arrangement of windings, may be placed side by side or one above the other. With some systems the arm that carries the movable cut-out contact also carries one or

two of the magnets. Such a method is used with Adlake equipment, there being two sets of magnets, one set stationary and the other movable. The movable set carries one contact and is attracted to the sta-

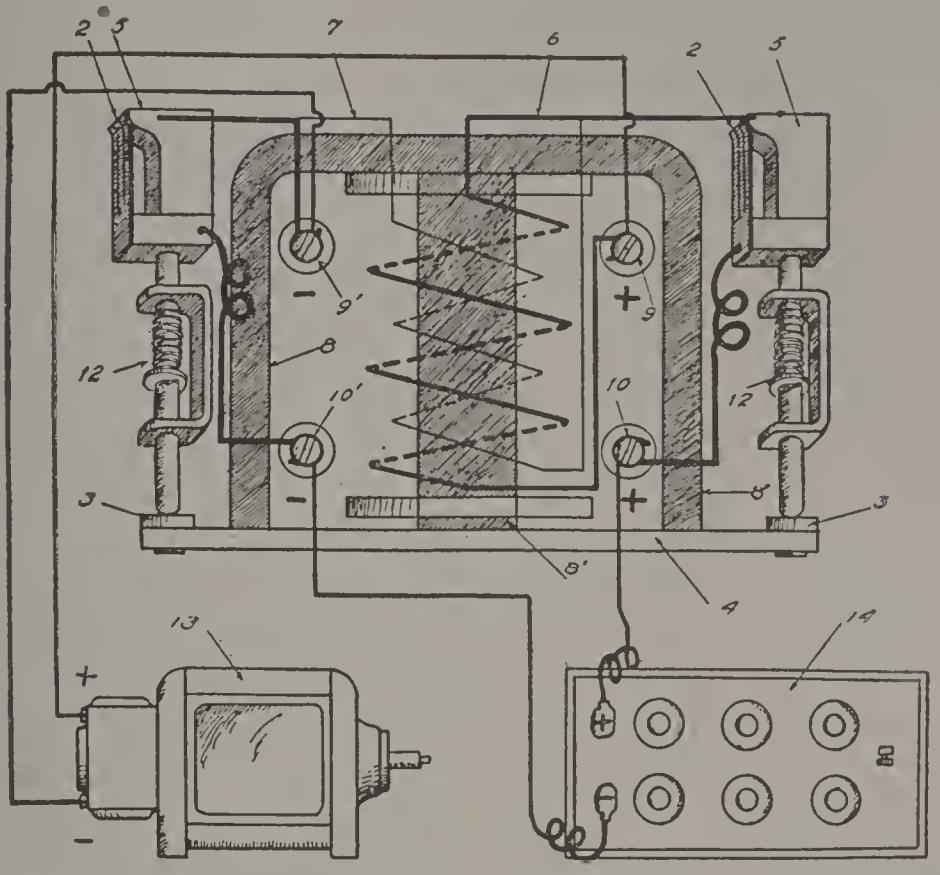


Figure 57.—Cut-Out to Break Both Sides of Circuit (Leece-Neville).

1—Battery Leads.
2—Movable Contacts.
3—Bumpers on Magnet Armature.
4—Magnet Armature.
5—Stationary Contacts.
6—Series Magnet Winding.
7—Shunt Magnet Winding.
8—Magnet Pole Pieces.
9—Terminals for Dynamo Leads.
10—Terminals for Battery Leads.
12—Springs for Plungers.
13—Dynamo.
14—Battery.

tionary set which is on top. The weight of the lower movable set is depended on to open the contacts and no spring is used.

Cut-outs are sometimes made with two sets of contacts, one set being on the positive side of the charging

circuit and the other set on the negative side. This type of cut-out will have four terminals, as shown in Figure 57. Four terminal instruments have been used with Leece-Neville and with Wagner systems.

It will be realized that a small flow of current is passing through the cut-out when the contacts open, this being the current that is passing from the battery through the series coil and dynamo and also that passing through the shunt coil. Breaking any circuit through which current is flowing will cause a spark and this spark is intensified when, as in this case, a

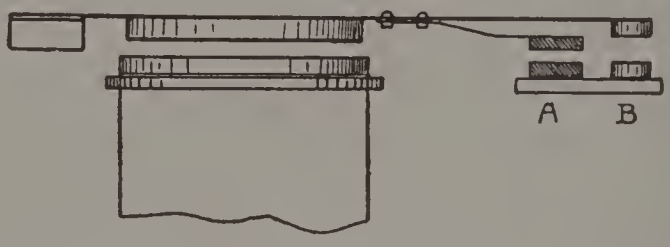


Figure 58.—Double Contacts for Cut-out. A—High Resistance Contacts to Take Spark. B—Low Resistance Contacts for Charging Current.

coil of wire is included in the circuit. To prevent this sparking from causing damage to the contacts the construction shown in Figure 58 is often used. The two contacts are shown at *A* and *B*. Contacts *A* are made from carbon or any other material that is a fairly good electrical conductor and that is not easily affected by sparking. The upper or movable contact of the pair marked *A* is carried on a small flexible extension of the main cut-out arm and the contacts of this pair are closer together than the pair marked *B*. Both of the upper contacts move at the same time when the cut-out armature is attracted to the magnet, but the pair marked *A* will close before those marked *B* and when the armature is released by the magnet

they will open before those marked *B* open. Contacts *B* are those depended on to carry the bulk of the current and they are made from metal of low resistance which would be damaged by excessive sparking.

The action is as follows: The contacts *A* close first, but as the armature is attracted further, contacts *B* will also close because the flexible arm carrying the upper contact *A* will bend slightly. With both pairs of contacts together the current flows through both of them, but most of it passes through the contacts *B*. When the cut-out opens, the contacts *B* separate first, but as current can still flow through contacts *A*, no spark is produced at *B* because the circuit has not been completely broken. As the armature moves away from the magnet to the full distance, the contacts *A* also open and the spark takes place between them. Because of their higher resistance the current flow has already been reduced to such a point that the spark that does take place is not so severe as if the circuit had been broken at its full strength.

Cut-out Adjustment.—The time, or dynamo speed, at which an electromagnetic cut-out will operate depends on two adjustments. One of these is the tension of the spring when a spring is used, and the other is the distance between the magnet core and the armature of the magnet. With increased spring tension the voltage, and consequently the dynamo speed, required will be increased. With an increased air gap between the magnet core and its armature the voltage and dynamo speed necessary to close the contacts will also be increased. Making the spring tension less or decreasing the air gap will lower the dynamo and car speed at which the cut-out closes. Increasing the spring tension or widening the air gap

will raise the dynamo and car speed of cut-out closing. Some systems provide for one method of adjustment, some for the other and some for both. In some cases no special provision has been made for either method of adjustment, but one or the other of these conditions can always be changed. In making cut-out adjustments the following points should be considered. With the cut-out open the magnetism must act across the air gap and consequently this gap affects the speed and voltage of cut-out closing. With the contacts once closed there is little or no air gap between the magnet core and its armature, and therefore the length of the gap has no effect on the time at which the cut-out will reopen. On the other hand, the spring tension is not much changed whether the cut-out be open or closed, and therefore the spring tension will affect the opening and closing about equally.

The cut-out should close just as soon as the dynamo voltage is above that of the battery. With a six-volt battery, the cut-out should close when the dynamo voltage is between 7 and 7½. With batteries of more cells and higher voltage, the dynamo voltage of closing should be in proportion. The cut-out should open when the discharge current flowing through the series coil and from the battery is between zero and two amperes. Improper operation may take place in any of the following ways:

1. Closing at a voltage below that of the battery. This will allow a discharge to take place until the dynamo runs fast enough to raise the voltage. Either the spring tension may be increased or the air gap increased.

2. Closing at a voltage much higher than that of the battery. This will prevent charging at speeds as low as might be used, and the time during which the car is operating below the cut-in speed is lost as far as battery charging is concerned. The remedy is to lessen the air gap or decrease the spring tension.

3. Closing at too high voltage and remaining closed until an excessive discharge takes place. This will lessen the total time during which the battery charges and will increase the time of discharging. Lessen the air gap and increase the spring tension.

4. Closing at too high a voltage and opening before a discharge takes place. Decrease the spring tension.

5. Closing with the dynamo voltage equal to or below that of the battery and remaining closed until an excessive discharge takes place. Allows the battery to discharge. Increase the spring tension.

6. Closing at too low voltage and opening before a discharge takes place. Decrease the spring tension and increase the air gap.

The current carrying contacts of the cut-out must be kept clean and bright and must meet with their whole surfaces in contact. Should the contacts be found dirty or pitted they may be properly fitted by passing a narrow strip of very fine emery cloth between them, then pressing them together and drawing the cloth back and forth. After one contact is cleaned the cloth should be turned over and the surface of the other contact treated in the same way. It should be

noted that some contacts are made with a ribbed surface and such forms should not be dressed with emery cloth, as this would destroy the ribs. This method of cleaning may be applied to contacts of metal or of carbon. Carbon contacts can be handled very satisfactorily with fine sandpaper or cloth in place of emery cloth.

The contacts of an electromagnetic cut-out should not be pressed together unless one of the wires from either battery or dynamo can be quickly removed. With the contacts together the flow of battery current around the series coil and through the shunt winding may hold them closed with a resulting discharge from the battery. All cut-outs are not subject to this action, those in which the armature never comes very close to the magnet core generally being free from it. Removing the wire that leads to the dynamo or the one that leads to the battery will stop the flow of current and will allow the contacts to open. Starting the engine will stop the flow from the battery and send it in the other direction. When the engine is allowed to stop, the contacts will open.

Various locations are used for electromagnetic cut-outs, these varying with the design and make of the equipment. In some cases this part of the apparatus will be found inside of the dynamo housing, either in the brush and commutator compartment, in a housing adjacent to the brushes and commutator or underneath the arch of inverted U magnets. The cut-out will oftentimes be carried on the outside of the dynamo case. Either of these methods allow of the minimum length of wiring between dynamo and cut-out and make it necessary to run only two wires away from the dynamo with a two-wire system or one wire

with a one-wire system. Other locations for the cut-out are on the dash, under the front seat, under the floor boards, on the cowl board, with the regulating device or with the starting, lighting or ignition switch.

Hand-Operated or Manual Cut-outs.—A number of systems are built in which the electromagnetic cut-out is dispensed with and in its place is used some form of switch that breaks the connection between the dynamo and battery when the engine is not running. This type of cut-out switch is attached to the same

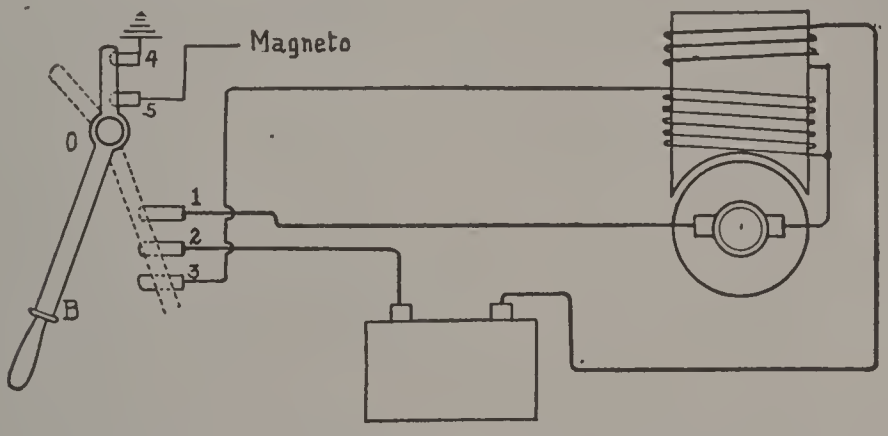


Figure 59.—Manual Cut-Out and Starting Switch (Dyneto-Entz Type).

handle, button or lever that operates either the starting switch or the ignition switch. When attached to the starting switch the ignition is also operated by the starting switch handle so that it might be said that a manually operated cut-out will always be interconnected with the ignition switch in such a way that the circuit will be closed between dynamo and battery when the ignition is turned on and will be broken when the ignition is stopped.

The action of one form is shown in Figure 59. This type of switch has been extensively used with Dyneto and with Entz equipment, and one similar in principle

has been used with Westinghouse and Bijur systems, always in connection with a combined motor-dynamo having one armature and operating as a starting motor at low speeds while changing to a dynamo at higher speeds. The switch is composed of a blade and handle *B*, pivoted at *O*. The position with the engine idle is shown in full lines, while the starting and running position is shown in dotted lines. The form illustrated is designed for use with a high tension magneto and in the off position the line from the magneto armature is grounded through the contacts *4* and *5* which are connected by the short extension of the switch blade on one side of the pivot.

With the switch moved to the running and starting position, the magneto ground is removed and the ignition will become operative. At the same time the current flows from the right hand brush of the dynamo through the series field (reversed for regulating purposes during action as a dynamo) and to the battery. From the left-hand brush current flows to switch contact *1*, through the blade to the contacts *2* and *3*. From contact *2* the charging current passes to the battery and from contact *3* a part of the current passes to the shunt field of the dynamo. Midway between the "Off" position and the "Start" or "Run" position, is a point called "Idle" or "Neutral." With the switch in this position, the ignition ground will be removed and the ignition operative, the contacts *1* and *2* will be connected so that the battery is connected to the starting motor, but contact *3* is disconnected so that the dynamo is prevented from generating because the shunt field circuit is not complete. This position would be used for touring or when the battery has been sufficiently charged.

A variation of this switch is shown in Figure 60 in which the leads to the contacts have been changed. The ignition and starting connections are the same in effect, but with the switch in the position half way between "Off" and "Start" the battery is disconnected and the shunt field is open so that no flow can take place from battery to motor-dynamo at low engine speeds and neither can current be generated by the machine as a dynamo. This has the effect of pre-

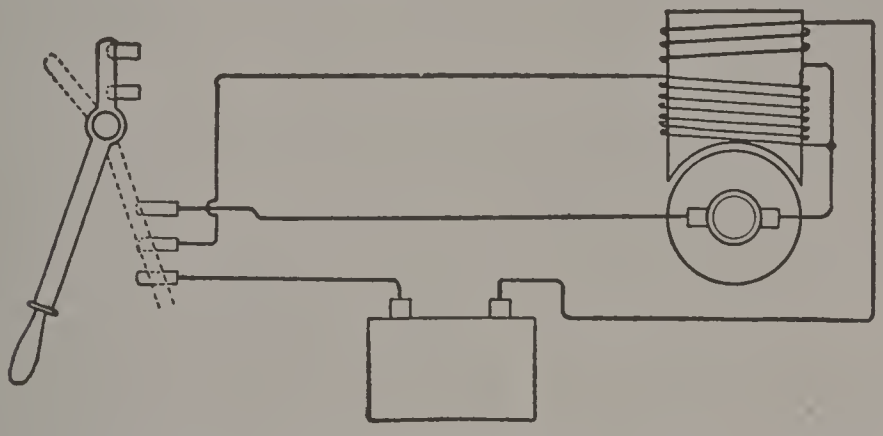


Figure 60.—Manual Cut-Out and Starting Switch (Dyneto-Entz Type).

venting useless battery discharge when the car is being operated at speeds so low that the dynamo voltage would not be high enough to charge the battery. It also prevents the generation of current while the battery is disconnected because of the opening of the shunt field circuit. Except for this switch, current generated with the battery disconnected would have to flow through the field windings and would be so much greater than these windings are designed to carry that the coils would be burned out. This connection, shown in Figure 60, is the one most used. Similar arrangements are secured by the use of switches of rotary form rather than the knife type

shown. The principle and the connections made remain the same, regardless of the style of switch used.

A type of cut-out switch that is operated with the ignition switch and that has been used with a great many Delco equipments is shown in Figure 61. When the switch button is pulled out, the contacts *A* and *B* are both closed at the same time. Current for ignition then flows from the battery through the wire to switch terminal *1* and through the wire *X* and the circuit breaker (not shown) to the ignition contacts *A*. From

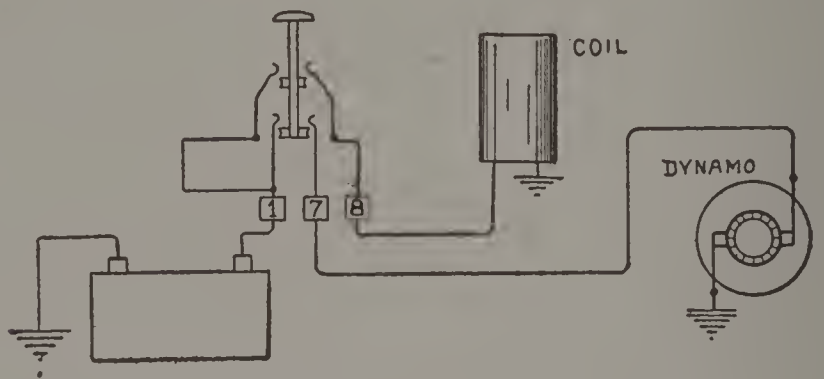


Figure 61.—Manual Cut-Out Switch (Delco).

these contacts the flow continues through switch terminal *8* to the ignition coil and then through the ignition breaker to ground, from where it returns to the battery.

With the ignition turned on as described, the engine can be started. The dynamo will quickly generate a voltage high enough to cause battery charging, and the flow will take place from the dynamo commutator to switch terminal *7*, then through the contacts *B* and through the terminal *1* to the battery. Part of this dynamo current will then pass through the ignition contacts of the switch and will take the place of the battery current supplied while starting the engine. One side of the battery and one side of the dynamo

are grounded so that the charging circuit is completed. A discharge of current will take place from the battery through the switch terminals *1* and *7* and through the contacts *B* during the time that the switch is closed and before the engine starts. This reverse flow or discharge will also take place when the engine runs at a speed so low that a charging voltage is not maintained. The proportion of discharge to charge is so very small that its effect on the battery is negligible. When the engine is to be stopped the switch is opened by pressing in on the button and both the ignition and charging circuits are broken. The dynamo is then disconnected from the battery while the engine remains idle.

It is of course impossible to make any adjustments on hand-operated cut-out switches because of the fact that their operation depends on the time at which either the starting switch or the ignition switch is used.

DYNAMO OUTPUT CONTROL

The details of the methods in use for limiting and regulating the battery charge rate in amperes are many. While the applications of the several principles differ more or less from each other in almost every make and every type of equipment, they may be divided into several distinct classes, according to the ways in which they secure the desired result.

Constant Voltage or Control of Current.—All methods of regulation may be classified under two heads. One class causes the dynamo voltage to remain at a constant and unvarying point after the cut-out closes, while the other class makes use of principles that allow the voltage of the dynamo to change so

that the desired flow in amperes is given to the battery through control of the voltage, but not through keeping it at a constant value. While both methods are in common use, the latter has been used in greater numbers than has the first one.

The rate of flow in amperes from the dynamo to the battery always depends on the difference in voltage between these two units. Should a battery with a pressure of six volts be attached to a dynamo that was generating exactly six volts, there could be no flow, because the two pressures would balance each other. The condition would be similar to that which would exist with a water tank attached to a water pump when the pressure in the tank was six pounds and the pressure from the pump was also six pounds. It is evident that there could be no flow in either case.

It will be remembered from the explanation of volts, amperes and ohms in Chapter I that the amperage flowing through a circuit may be found by dividing the voltage by the resistance of the circuit. The resistance of the wiring and connections between dynamo and battery, plus the resistance of the battery itself, make up the total resistance of the charging circuit, and the voltage acting will always be the difference between that of the dynamo and of the battery. For purposes of explanation, it may be assumed that the resistance through the charging circuit will remain unchanged at all times, and in the following explanation on this subject, this condition has been taken for granted.

It will then be evident that any increase of dynamo voltage above that of the battery will result in an increased flow and the change of flow will be in proportion to the change in difference of voltage between

dynamo and battery. Two things will always act to increase the dynamo voltage with a straight shunt wound machine, these being increase of armature speed and increase of current flowing around the field coils. With a shunt wound dynamo these will increase together for the reason that increased voltage at the brushes caused by increased speed will result in an increased flow through the field windings because of this higher voltage. The total result will be a still further increase in generated voltage, also a corresponding increase of amperage through the circuit.

The dynamo armature is generally driven positively from the engine at all speeds so that its speed increases directly in proportion to increase of car and engine speed. The dynamo voltage would therefore naturally rise continuously from the lowest to the highest speeds. In some cases the speed is limited by a governor that releases the driving connection when the desired number of revolutions per minute has been reached and the dynamo cannot generate a voltage in excess of that caused by this maximum speed. With the generally used type of dynamo operating at a variable speed the method of output control will act to decrease the field strength with increase of speed so that the weakened field counteracts the more rapid rotation of the armature to a greater or less extent and the dynamo voltage is held within certain desired limits. Another method makes use of the change in direction of the lines of force through the armature. Depending on the method used, any of the following effects may be secured:

1. An increase of voltage throughout the whole range of dynamo speed, the voltage, however, increasing less rapidly at high speeds than at low.

2. A gradual increase of voltage until a maximum is reached at some critical speed, followed by a falling off in voltage as the speed becomes still greater.

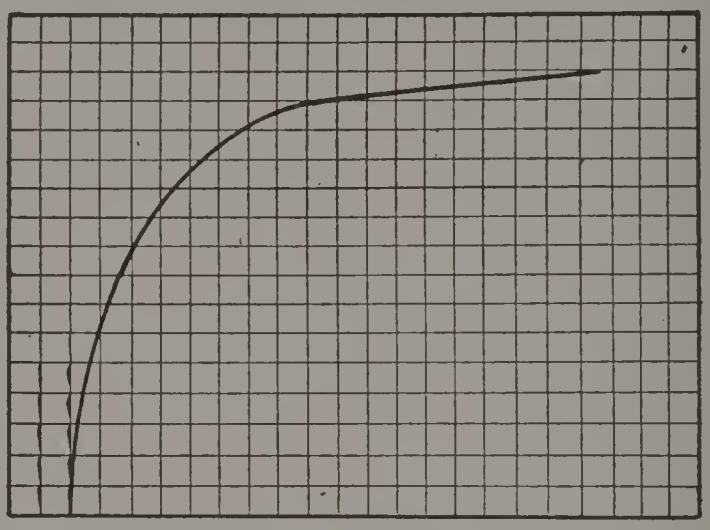


Figure 62.—Output of Dynamo Having Gradual and Continuous Increase (Reversed Series).

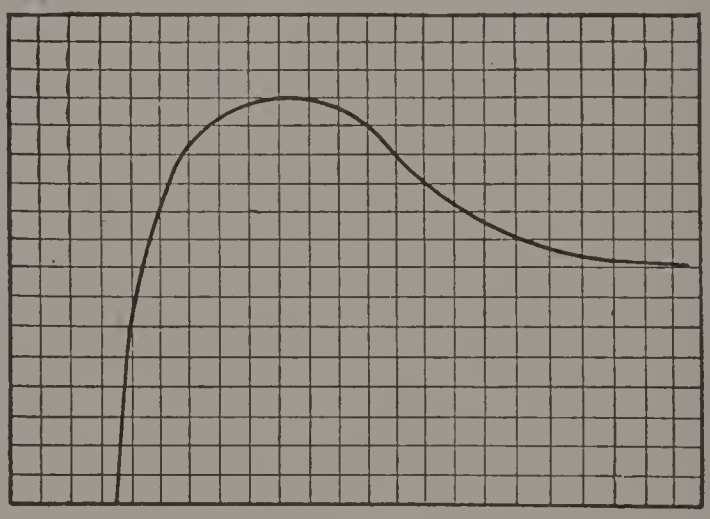


Figure 63.—Output of Dynamo Having Quick Rise to Maximum, Followed by Decrease (Third-Brush).

3. A comparatively sudden rise in voltage through the low speed ranges until a critical point is reached, after which the voltage is maintained at a point just

sufficient to cause a constant amperage to flow from dynamo to battery.

The characteristics of the three types are shown in Figures 62 to 64. The rate of speed corresponds to the series of vertical lines, and increases from left to right. The voltage and consequent amperage flowing are indicated by succession of horizontal lines, and the increase is from bottom to top. Figure 62 represents the condition numbered "1" in the fore-

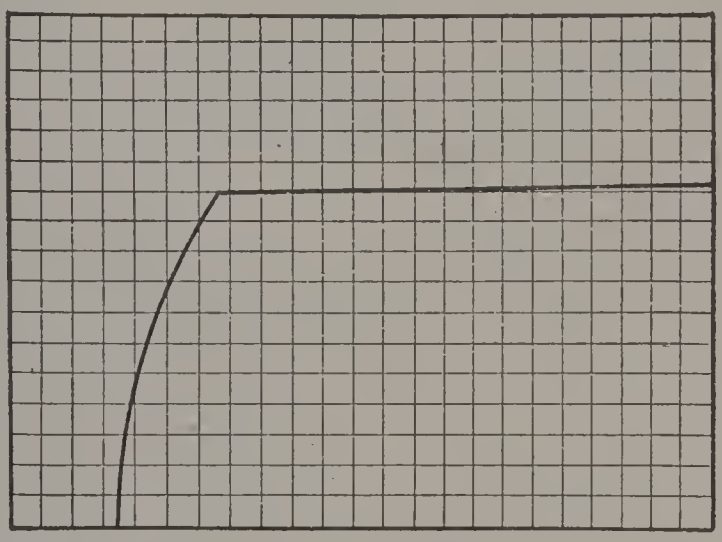


Figure 64.—Output of Dynamo Having Constant Amperage Regulation.

going explanation. Figure 63 represents the condition outlined in number "2," while Figure 64 shows the result obtained in number "3." These types include the methods that are classed as amperage control, or limited output control, but do not represent the second general classification known as constant voltage or "constant potential."

Constant Voltage.—It was explained in Chapter III that the voltage of the battery increased as the charge progressed and that the voltage of a fully charged battery is higher than the voltage of a battery that is

discharged or partially discharged. If a dynamo is operated in such a way that the voltage generated will remain constant at one value over practically the whole range of armature speed it will be seen that the difference in voltage between the dynamo and battery will depend not only on the dynamo but also on the voltage of the battery at any particular time. With a nearly discharged battery of low voltage, the difference between dynamo and battery will be compara-

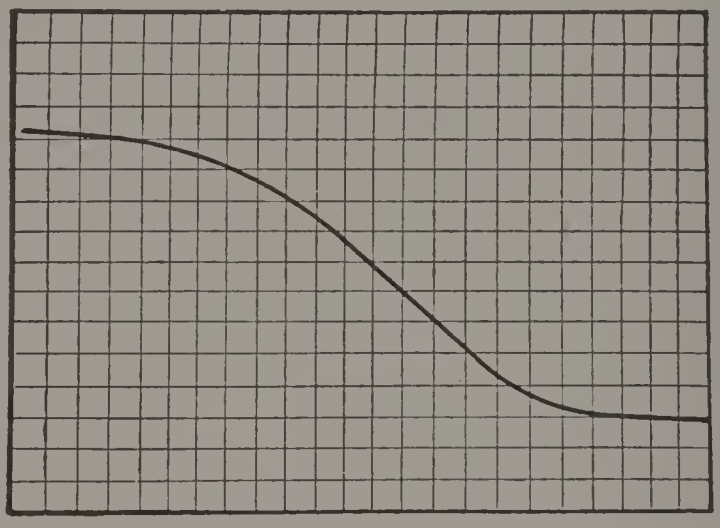


Figure 65.—Output of Dynamo Having Constant Voltage Regulation.

tively great, while with a battery that is nearly charged and of correspondingly high voltage, the difference will not be so great. For this reason the flow from the dynamo to a discharged or partly charged battery will be caused by a comparatively large difference of voltage, and this flow will be relatively great in amperage. The flow from the constant voltage dynamo to a battery that is nearly or fully charged and of correspondingly high voltage will be caused by a smaller difference in pressure, and the amperage will therefore be relatively small. This

action gives what is known as a "tapering charge," that is, a charge whose amperage becomes less and less as the battery becomes charged and as the battery voltage increases. The characteristics of such regulation are shown in Figure 65, in which the percentage of battery charge from zero to full charge is shown from left to right while the amperage or voltage difference is shown by the horizontal lines and decreases from top to bottom. In this connection it should be borne in mind that the specific gravity of the battery electrolyte increases with increase of battery voltage, and it may therefore be stated that the rate of charge in amperes will be greater at low specific gravities than at high.

Output or Voltage Regulation.—Four principal methods or devices are in use for securing control of the dynamo voltage and output. They may be classified as follows:

I. Inherent characteristics of the dynamo design that do not require the use of any additional moving parts but that secure the desired results through the peculiarities of electric currents, conductors and magnetism. This class includes compound and reversed-series field windings, also a variation somewhat similar to the reversed series and known as a "bucking coil." A type of dynamo having one or more brushes in addition to those for the charging lines is also included in this class, this type being known as the "third brush" machine. In this case the added brushes carry the field current for the shunt winding.

II. Electromagnets that act to increase the resistance of the shunt field circuit, or to open the shunt

field under certain conditions, or to make changes in the field circuits.

III. Centrifugally operated governors that act to prevent an armature speed above a predetermined limit or that insert a resistance in the field circuit or charging circuits.

IV. Ampere-hour meters that change the field circuit resistance according to the number of ampere hours that pass into or out of the battery.

The four classes just mentioned are found in a total of sixteen different applications, each of the sixteen being a distinct type of regulation and used by one or more makers of electrical equipment. Each application will be described, and when used by a limited number of makers, their names will be given in connection with the description. The applications under each division are as follows:

I. Inherent Characteristics.
   (1) Reversed-series field winding.
   (2) Third brush for shunt field current.
   (3) Compound field windings.
   (4) Bucking coil (iron wire control).

II. (5) Magnetic vibrator inserting field resistance.
   (6) Magnetic vibrator energizing bucking coil.
   (7) Magnetic vibrator for field resistance, with load control.
   (8) Magnetic controlled carbon field resistance.
   (9) Magnet acting to open field circuit.
   (10) Solenoid operating rheostat field resistance.

(11) Magnet and mercury well control of field resistance.
(12) Changing combinations of fields and windings.

III. (13) Speed control governor with compound field winding.
(14) Speed control governor with permanent field magnets.
(15) Governor inserting field resistance.

IV. (16) Ampere-hour meter control of field circuit.

The numbers that appear at the beginning of each of the following descriptions refer to the numbers given in the foregoing list of applications.

(1) The principle upon which the reversed-series field winding system operates has been described in Chapter II, and a lengthy description is therefore unnecessary at this time. The application of this method of regulation in one type of Auto-Lite dynamo is shown in Figure 66. This machine carries two windings on each of the field magnet poles, one winding being the usual shunt and the other one being a series coil through which the current, passing from dynamo to battery, flows in a direction the reverse of that taken by the current passing through the shunt coils. From the lower brush, which is positive, current passes to both coils on the lower pole piece, part passing through the shunt field in such a direction that this pole end is made positive. This current is then carried to the upper shunt field winding and passes around this upper pole piece in such a direction that

its end is also made positive. The consequent poles thus formed at either side of the armature are therefore negative.

The portion of the current from the positive brush that is not required for the shunt field, passes around

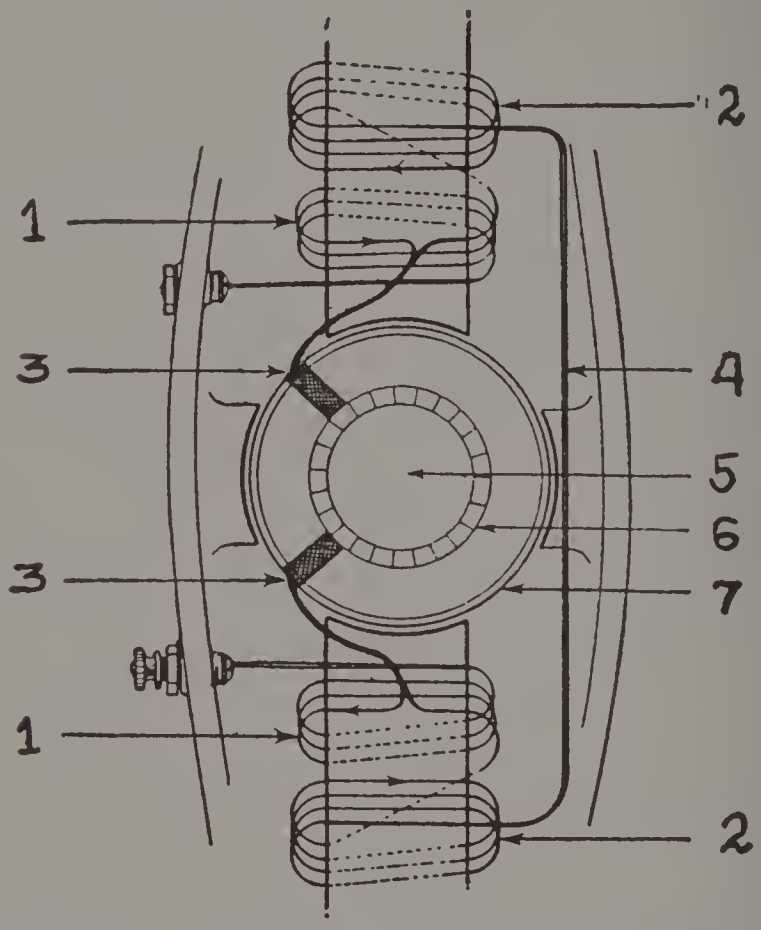


Figure 66.—Dynamo Having Reversed Series Regulation (Auto-Lite).

1—Series Field Windings.
2—Shunt Field Windings.
3—Brushes.
4—Connection for Shunt Windings.
5—Dynamo Shaft.
6—Commutator.
7—Armature.

the lower pole piece in a direction that tends to oppose the shunt winding and to make this pole end of less strength. After passing around the magnet, the current is led to the lower terminal and then to the battery. The current returning from the battery to the

upper dynamo terminal, comes into the upper series winding and passes around the magnet in a direction that tends to weaken this upper pole, thus opposing the shunt winding. Having traveled around the windings, the current joins with that from the upper shunt coil and is led to the negative brush. While this exact method of winding is not always followed, the principle is the same in all applications of this method, that is, to cause the charging current passing around the series windings to oppose the effect of the shunt winding.

(2) Third brush regulation depends on two electrical facts. One is the fact that the voltage between a brush of a two-pole dynamo and point on the commutator away from this brush depends on the distance of the point from the brush and becomes greater as the distance increases. The greatest voltage difference will therefore be secured between opposite points on the commutator. If one end of the shunt field winding be connected to one brush and the other end of the winding lead to a brush that is not directly opposite the first one, the difference in voltage acting to send current through the shunt field will not be as great as if the field were connected between brushes directly opposite. If, then, the field current is to be increased, the second brush may be moved farther away from the first one and this movement will allow a greater difference in voltage to act on the field and a correspondingly greater flow in amperage and field strength will result. The field strength may be decreased by bringing the brushes to which the winding is attached nearer together. The brush that carries one end of the winding is generally made movable, and the output of the dynamo may be increased or de-

creased by moving the brush away from or toward the stationary brush. While such brushes may be made movable for purposes of adjustment, they are locked in one position while the dynamo is in operation, the control of voltage being secured, not by continually moving the brush, but as described in the following paragraphs.

The connections for regulation in such a system are shown in Figure 67, the type shown being used with several models of Remy dynamos. The principle and

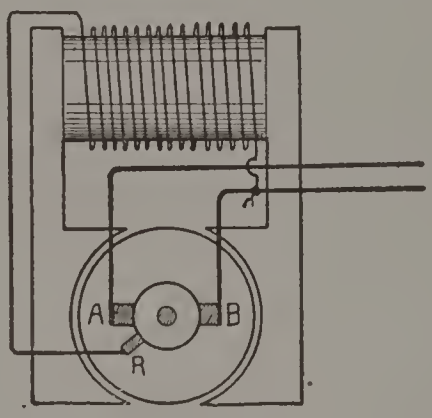


Figure 67.—Dynamo with Third Brush Regulation.

action will be the same, regardless of the make of equipment or its model, so long as the third brush system is used. Current for charging is taken from the main brushes marked *A* and *B*, these being indirectly connected to the battery. The shunt field current passes through the brush *R* and to the field coil, then through the field fuse which is used to protect the field winding against excessive current flow, and from the fuse the field current returns to the brush *B*. The difference in voltage between brushes *R* and *B* is the voltage that acts to send current through the field coil. Were it possible to change the regulating brush position, moving it down (toward brush *B*) would de-

crease the output of the dynamo, while moving it up (farther from *B*) would increase the output.

At low speeds the flow of magnetism or magnetic lines of force between the poles of the field magnet is shown in Figure 68. It will be seen that the flow is practically straight across, and because of this direction of the lines of force through the armature, the coils which are at any instant in connection with the brushes, cut through the greatest possible number of lines of force, and therefore the greatest difference in voltage will be between the commutator points being touched by the main brushes *A* and *B*. A less dif-

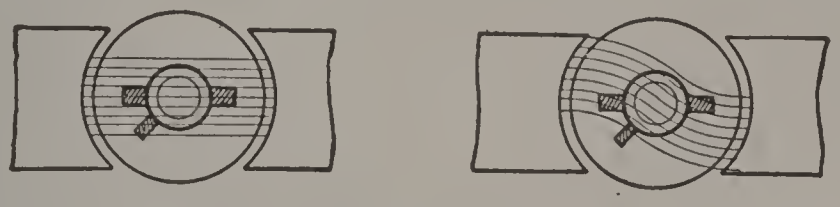


Figure 68.—Distortion of Field Magnetism for Third-Brush Regulation.

ference in voltage will be maintained between the points touched by the brushes *R* and *B* because of the smaller number of lines of force being cut by the corresponding armature coils.

With increase of armature speed, the lines of force do not continue to pass straight across, but are carried part way around in the direction of rotation by the core of the armature. With the magnetism flowing in this distorted path, the armature coils that are at any one time attached to the regulating brush through the commutator, are not cutting as many lines of force as at lower speeds, and the voltage difference between the brush *R* and the brush *B* is less than with the lines of force passing straight across. This reduction of voltage causes the amperage passing through

the shunt field to decrease, and even with the rise in armature speed, the output does not increase proportionately because of the weakened field. With further increase of armature speed, the path of the lines of force is still further distorted and the field current drops to such an amperage that the total output of the dynamo becomes less and less through the highest speeds of rotation. The relation of dynamo output to armature speed is shown by the curve in Figure 63.

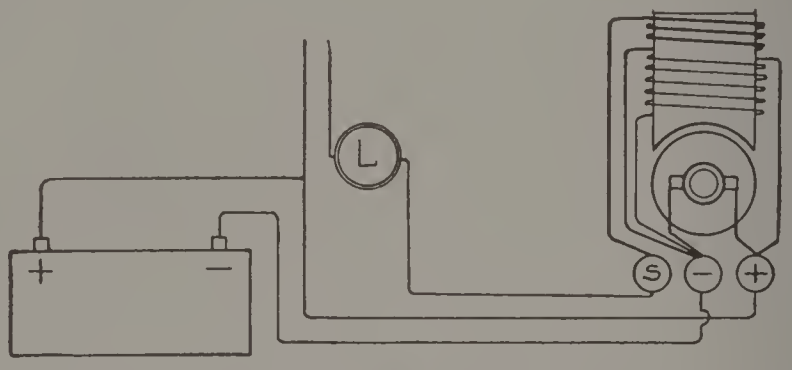


Figure 69.—Compound Wound Dynamo with Lamp Circuit Through Series Field (Gray & Davis).

(3) The compound-wound dynamo is generally used in combination with some of the other methods of regulation. This machine makes use of a straight shunt winding on the field magnets, and in addition to this shunt winding, has a series coil through which current flows in the same direction as through the shunt and increases the field strength. Such an arrangement is shown in Figure 69, this connection being that used with some older types of Gray & Davis dynamos that were equipped with a centrifugal governor to limit the dynamo speed.

In this case it will be seen that current for the lamps is carried through the series field winding, and when

the lamps are lighted, the strength of the series winding will be added to that of the shunt with a consequent increase in dynamo output to care for the added load placed upon the system by the lighting of the lamps. With no lamps lighted, current from the dynamo brushes flows to the terminals marked + and – and from these terminals to the positive and negative terminals of the battery. Should the lamps be turned on, the current taken by the bulbs will not pass to the battery, but from the + dynamo terminal through the wire *A* to the lamps, then through the lighting switch *L* and wire *B* to the dynamo terminal *S*. From this terminal the lamp current passes around the series coil, then to the dynamo terminal marked – and back to the negative brush. Should enough lamps be turned on to take more current than that being supplied by the dynamo, the deficiency will be furnished by the battery. This extra current will come from the positive battery terminal to the lamps, then through the bulbs and lamp switch to dynamo terminal *S*, through the series field so that it is still further strengthened and back to the battery from the dynamo terminal marked –.

(4) The system of regulation known as "iron wire" control was introduced on the dynamos made by the Rushmore Dynamo Works and is also used on some of the products of the Bosch Magneto Company of which the Rushmore Dynamo Works is a part. The dynamo field magnets carry a shunt winding, and in addition to the shunt, a second winding of fewer turns through which current is forced to flow in a direction opposite to that in the shunt coils by a peculiar property of iron wire. A field coil, so wound that current passes

through it in a direction that opposes the shunt field action, is called a "bucking coil." In this case the coil is not a series coil and does not carry the entire dynamo output, therefore the system cannot be classed as a reversed-series type.

Iron wire will carry a volume of current in proportion to the gauge size, just as any other metal carries current. Up to a certain amperage the wire will remain comparatively cool, but as soon as this amperage is exceeded, the wire will become very hot and

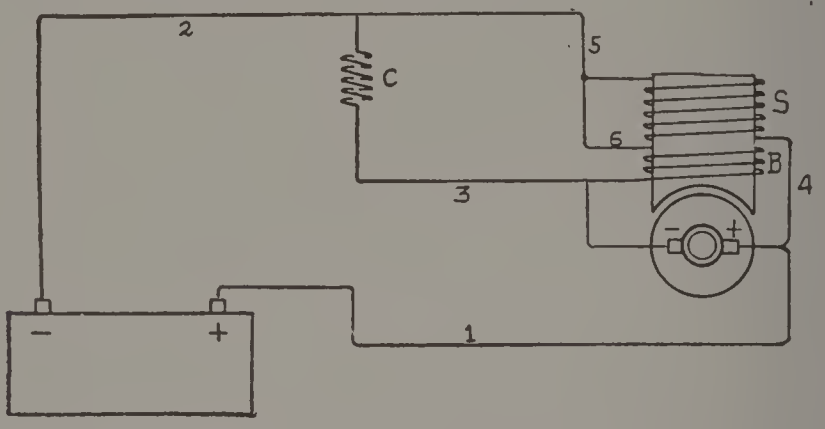


Figure 70.—Principle of Rushmore Iron Wire Regulation.

with increase of temperature, its resistance increases to such a point that but very little flow of current can take place through the wire.

The use of iron wire in the Rushmore system is shown in Figure 70. Starting at the right-hand brush, the charging current flows through wire *1* to the battery, through the battery and by wire *2* to one end of the ballast coil *C*. This ballast coil is made from a certain gauge size of iron wire and always carries ten feet of the size used. Passing through the ballast coil and wire *3*, the current returns to the negative dynamo brush. Again starting at the right-hand brush, the field current passes through wire *4* to the

shunt field winding *S*, through the coil and by way of the wire *5* to the ballast coil, and through the iron wire to wire *3* and the negative brush. It will thus be seen that the bucking coil field winding *B* carries practically no current under ordinary conditions.

When the amperage reaches a certain value, the iron wire becomes very hot and further increase of current flow through it is prevented. This prevents increase of flow through wires *5* and *3*, and the field current that formerly passed through wire *5* must now take the path through wire *6*, through the bucking coil and to the negative brush. This flow of current through the bucking coil decreases the field strength and dynamo output. With decrease of output, the iron wire cools and the current again takes its normal path and leaves the bucking coil weak as before. By selecting a gauge size of iron wire that will keep just below the critical temperature while carrying the desired charging current, the output of the dynamo is prevented from exceeding this amperage.

(5) A great many systems make use of a regulating device comprising an electromagnet whose strength increases with increase of dynamo voltage and which causes a high resistance to be temporarily inserted in the shunt field circuit when the dynamo speed becomes high enough to cause excessive voltage and therefore excessive amperage. The principle of such a mechanism is shown in Figure 71. The three dynamo terminals are marked *F*, *A* and *D*; *F* being attached to one end of the shunt field winding, *A* to one of the dynamo brushes, and *D* to the other brush and the remaining end of the field winding. The regulator consists of the magnet *M* around which current from

dynamo terminal *A* flows through the wire *1* on its way to the battery. It will be seen that this magnet will become stronger as the amperage passing from the dynamo to battery increases. The armature of this magnet is held away from the core by the spring *B*, and with the armature in this position, the contacts *C* are closed.

Current for the shunt field leaves the dynamo at terminal *A*, passing through the wire *1* to the contacts.

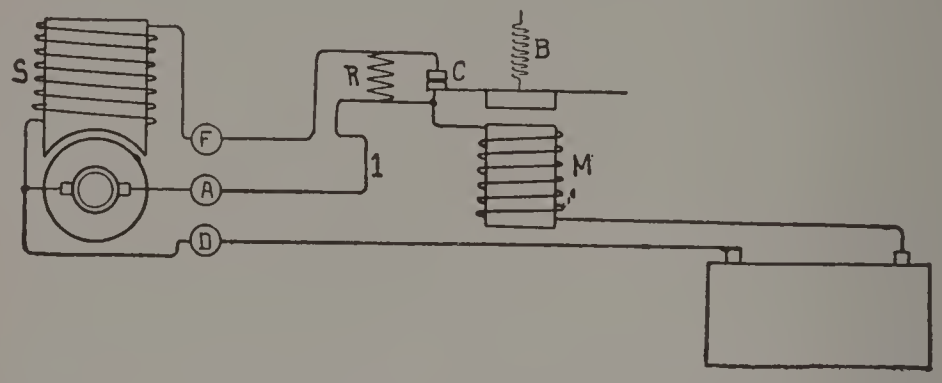


Figure 71.—Electromagnetic Regulator for Constant Amperage.

This current does not flow through the coil *R* because this coil is made from wire with a very high resistance, but the current takes the path of low resistance through the contacts. From the upper contact the field current passes to dynamo terminal *F*, through the shunt field winding and to the left-hand brush. As long as the amperage flowing to the battery around the magnet *M* is not great enough to cause the magnet to overcome the tension of the spring *B*, the above conditions hold true. The spring tension is set at such a point that when the desired maximum amperage of charging is reached, the magnet attracts its armature and the contacts *C* open. The field current can no longer pass through the contacts, but must take the path through the resistance coil *R*. This

resistance allows but a small current to pass through the field, with a consequent reduction in field strength and dynamo output. The decreased output results in a lessened flow around the magnet *M*, and the contacts are again closed by the tension of the spring *B*. In practice this opening and closing of the contacts is so rapid as to be almost imperceptible to the eye, and the field current is maintained at such a strength that the dynamo output cannot exceed the maximum for which the spring tension is set, regardless of dynamo

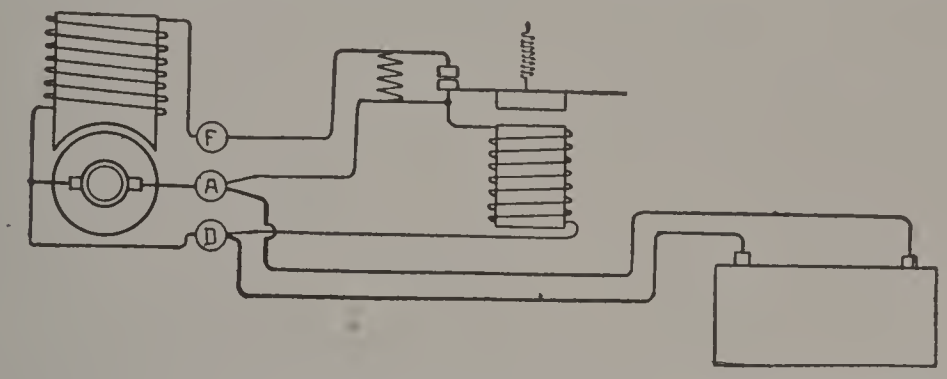


Figure 72.—Electromagnetic Regulator for Constant Voltage.

speed. Increasing the spring tension or increasing the air gap between magnet core and armature will raise the amperage that the dynamo will give, while decreasing the spring tension or lessening the air gap will result in a lower amperage for charging. This principle has been used in controllers made by Allis-Chalmers, Delco, Disco, Gray & Davis, North East, Remy, Simms-Huff, and Ward Leonard.

The variation of this method, shown in Figure 72, illustrates the connections when it is desired to maintain a constant voltage at the dynamo rather than a limited amperage, regardless of dynamo speed. The sole difference is that the magnet *M* now has its coil connected to the dynamo brushes through the ter-

minals *A* and *D*. Whatever voltage exists between the dynamo brushes will therefore act on the magnet winding. The strength of the magnet will increase with dynamo voltage, and will decrease with drop of dynamo voltage. The tension of the spring is set at a point such that the armature will remain away from the magnet core and the contacts will remain closed until the dynamo voltage reaches the value that is desired. At this voltage the magnet overcomes the spring tension, the field current is forced to pass through the resistance coil, and the lessened flow through the fields causes an immediate drop in voltage. This drop in voltage weakens the magnet so that the contacts are again closed by the spring, and the operation is repeated at an extremely rapid rate. The result is that the voltage of the dynamo will not rise above the point that the spring is set for, regardless of the dynamo speed. The magnet winding in this case is made from a great many turns of very fine wire, so that but little current will flow through it. The battery is connected between dynamo terminals *A* and *D* so that current for charging does not pass through the regulator. Increasing the spring tension or increasing the air gap between magnet and armature will raise the operating voltage of the dynamo, while decreasing the spring tension or the air gap will lower the dynamo voltage.

Systems using the vibrating form of regulator practically always make use of an electromagnetic cut-out with it. The two units are combined in one housing and called a controller. The controller may use two magnets, one for the regulator and one for the cut-out, or may use but one magnet with two windings for both functions. Such a combination is illustrated in

Figure 73. The single magnet is so arranged that it will attract the right-hand armature for cut-out action and the left-hand armature for regulator action. This magnet carries a fine wire coil *S* which is the shunt coil for the cut-out action, and also a coil of heavy wire *C* which acts as the series cut-out coil and as the main coil for the regulator in a way similar to that of the type shown in Figure 71. The field resistance is shown at *R* and the four terminals used with this type of controller at *F*, *A*, *DB* and *B* on the controller case.

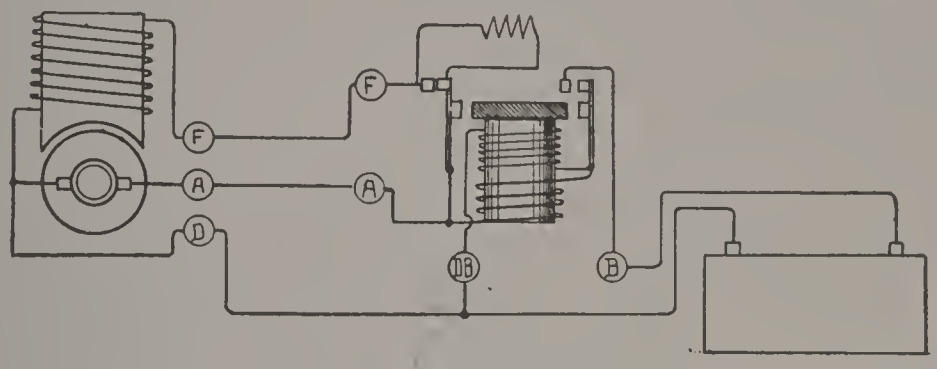


Figure 73.—Controller Connections with Magnetic Cut-Out and Constant Amperage Regulation.

The action is as follows: When the dynamo is idle, the cut-out contacts *Y* are open and the regulator contacts *X* are closed. When the dynamo generates a difference of voltage, current flows from dynamo terminal *A* to controller terminal *A*, through the coil *C* on the magnet, then through coil *S* to controller terminal *DB* and to dynamo terminal *D*. The field circuit is completed from dynamo terminal *A* to controller terminal *A*, through the closed contacts *X* and from controller terminal *F* to the dynamo field terminal, through the shunt field and to the left-hand brush. The flow of current around the magnet causes the cut-out contacts *Y* to close when the dynamo voltage is high enough to charge the battery, and the flow

from dynamo to battery passes through coil *C* to the contacts *Y* which are now closed, then to controller terminal *B* and to the battery. When the amperage flowing through the coil *C* reaches the desired maximum, the left-hand armature is attracted to the magnet and the contacts *X* are drawn apart. The field current then passes through the resistance *R* and the regulating action is the same as that already described.

(6) A vibrating system that is seldom met with makes use of a magnet similar to those just described. When the contacts are drawn apart by excessive amperage through the charging circuit, the field current is forced to pass around a series of bucking coils on the field magnet poles. The bucking coils thus take the place of the resistance used with the type described under (5). Jesco systems have made use of a vibrating regulator that utilized a resistance coil and also caused part of the field current to pass through bucking field coils.

(7) The diagram of the circuits of the Gray & Davis controller shown in Figure 74 illustrates the use of a magnetic vibrator that is affected by the lamp load in such a way that the output of the dynamo is automatically increased whenever lamps are lighted with the engine running. It will be seen that current from the positive brush flows through a ground connection for battery charging and that the current used for exciting the fields flows from the positive brush through the upper and lower fields and then to the controller terminals between which is fastened the resistance coil. The regulator contacts are normally closed so that the field current passes through

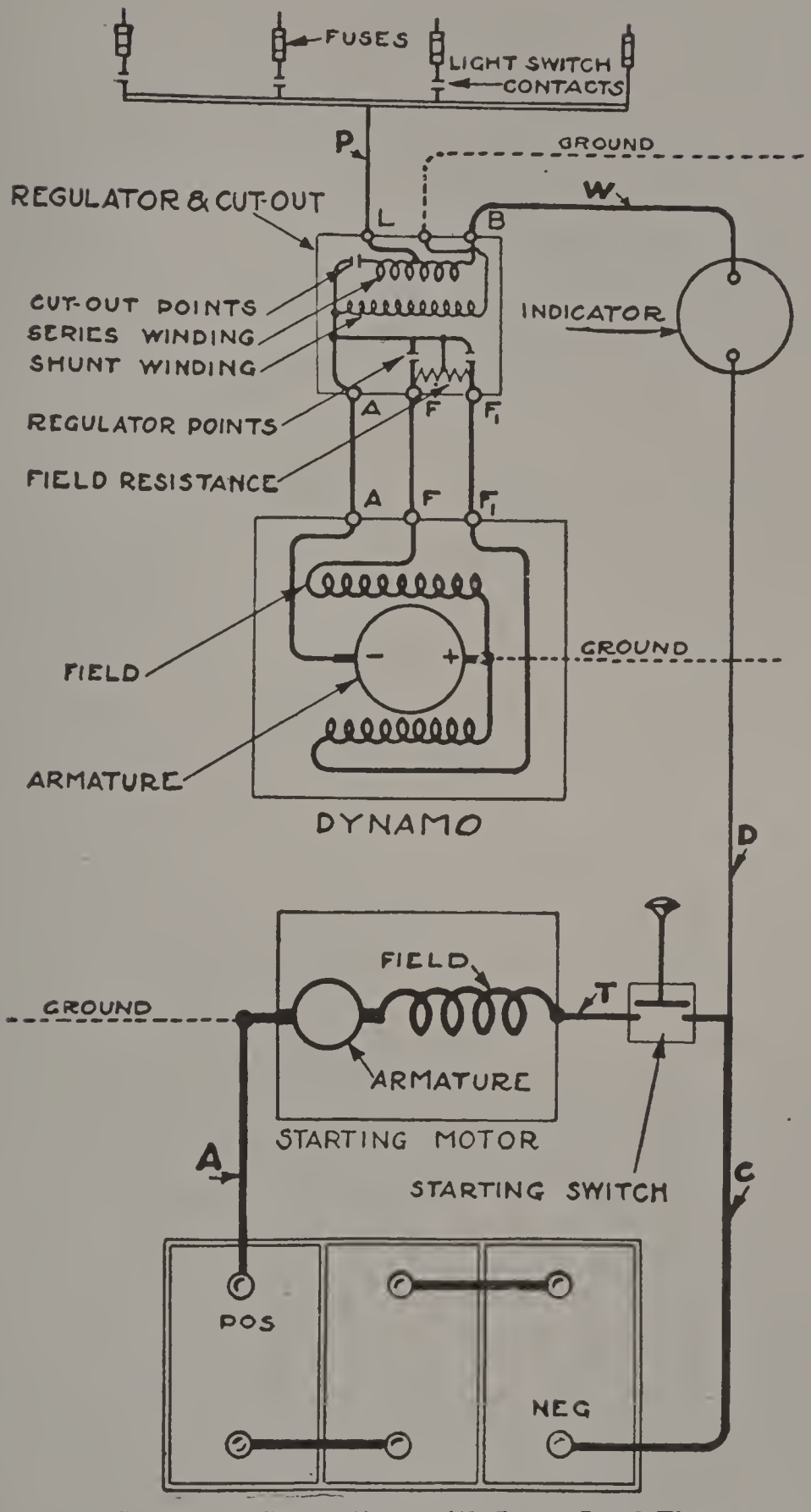


Figure 74.—Controller Connections with Lamp Load Through Windings (Gray & Davis).

them and by way of the wire back to the negative brush.

Current for the shunt winding on the controller magnet enters the controller through the grounded terminal, passes through the magnet winding and then through the controller terminal *A* to the negative brush. The positive brush is grounded so that the magnet circuit is completed, and the cut-out contacts will close when the dynamo voltage is high enough.

The path of the changing current is from the positive brush to ground and from ground to the battery. After passing through the battery, this current flows to the controller terminal *B*, through the series winding of the magnet and by way of the closed cut-out contacts and the terminal *A* to the negative brush. The series coil also acts as the regulator winding and when the amperage has reached the point for which the adjustment is set, the regulator contacts are drawn apart. The field current then flows through the resistance coil and this resistance reduces the dynamo output. The amperage flowing through the series magnet winding determines the point at which the regulator will act and accordingly limits the dynamo output.

It will be noted that the lamp circuits are attached to the controller terminal *L*, and current for the lamps must pass through this terminal. With lamps turned on, the entire flow of dynamo current would not return through the cut-out contacts to the negative dynamo brush, but a part of it would leave the series magnet winding at the point from which a connection leads to controller terminal *L*. The part of the current that is thus used for lighting does not pass all the way through the series winding, and the

strength of this winding is therefore reduced in proportion to the current flowing to the lamps. With a decreased strength of this magnet, the regulator contacts will not open so soon and the dynamo output will reach a higher value before the regulator acts. This additional output compensates in a measure for the current required for lighting. Devices of similar action are used with other makes of equipment, the application illustrated serving, however, to demonstrate the principle involved in all of them.

(8) The resistance of carbon is sufficiently great to make it well suited for use as field resistance. Two forms of carbon have been used for this purpose, one being a number of carbon discs, such as found in some models of U. S. L. and Aplco equipment, and the other being finely divided, or powdered, carbon mixed with flake mica, as used with the Bosch voltage regulator.

Carbon discs are used by carrying them in the form of a pile laid one against the other. They are normally held tightly together by the action of a spring, and in this condition their resistance is very low. The armature of the regulator electromagnet is attached to the spring bar in such a way that the power of the magnet acts to release the spring tension. This will happen when the amperage passing through the magnet becomes excessive. The carbon discs are thereby released, and the poor contact between adjacent discs interposes a high resistance in the field circuit, which is completed through the carbon, and the dynamo output is reduced.

When powdered carbon is used, it is carried in a cup and is compressed by a plunger. Attached to the

plunger is a rod that passes through a magnet winding, and with increase of amperage through this winding, and consequent increase of magnet strength, the pressure exerted by the plunger is released. The springiness of the flake mica then forces the particles of carbon apart, and the resistance of the mass is increased over what it would be in the compressed state. The field circuit is completed through the carbon mass and the plunger is held down by a spring. When the magnetism overcomes the tension at which the spring is set the field current is reduced and further rise of dynamo voltage is prevented.

All of the carbon resistance systems are adjusted by changing the spring tension. Increase of spring tension holds the carbon together until a higher amperage or dynamo voltage is reached and decrease of the tension lowers the output. The U. S. L. controller, Figure 75, is adjusted by turning a small screw to the end of which is attached the coil spring that holds the carbon pile pressure arm. The Aplco controller has an adjusting screw projecting from the bottom of the case, while the Bosch controller makes use of an oval shaped spring whose tension is changed by turning in or out on a tapered plug that passes over one side of the spring.

(9) The regulating device for one of the Aplco systems makes use of an electromagnet whose winding is connected across the terminals of the battery so that the magnet increases in strength as the voltage of the battery increases. The field circuit is completed through the contacts controlled by this magnet, and when the battery voltage reaches the point that corresponds to the tension of the adjusting spring,

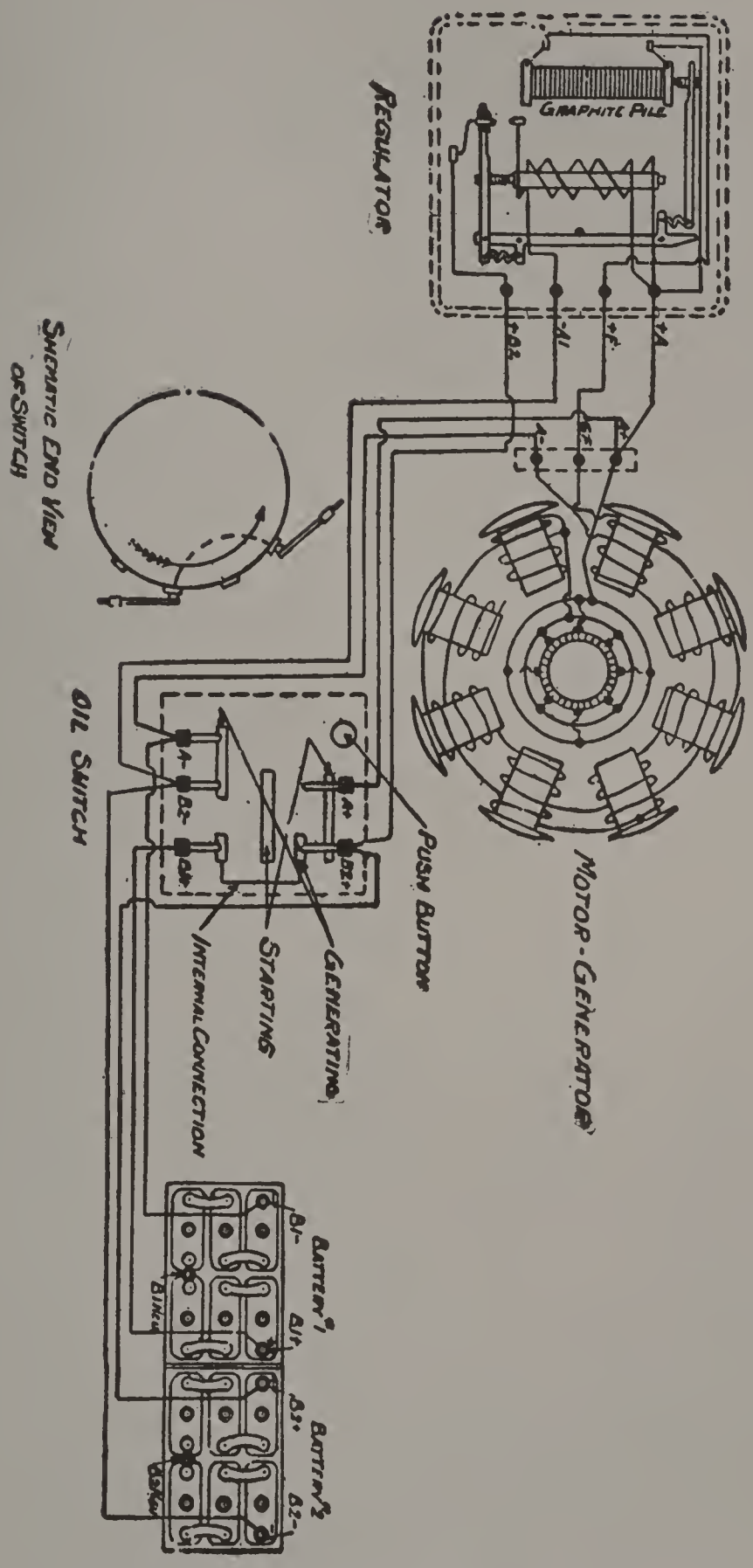


Figure 75.—Controller with Carbon Disc Field Resistance (U. S. L.).

the contacts open and, except for that passing through a resistance coil, prevent further flow of current through the shunt field of the motor-dynamo. This stoppage of the field current prevents further charge of the battery until its voltage falls.

(10) The controller used with Adlake equipment carries a rheostat which is controlled by the action of a plunger passing through the center of a magnet winding. See Figure 76. The rheostat consists of an arm pivoted at one end and carrying a carbon brush at the other end. This carbon brush travels over a series of contact segments as the arm moves up and down. One end of the field circuit is attached to the sliding arm and the other end to one end of the series of segments. Between each pair of adjacent segments is placed a small coil of resistance wire, and with the end of the arm resting on the contact segment farthest from the one carrying the end of the field circuit, it will be necessary for the field current to pass through each of the resistance coils in flowing from the arm to the end of the field circuit that attaches to the segments. With the arm resting on the segment to which is attached the end of the field circuit, the field current does not have to pass through any of the resistance coils. This latter position is the one assumed by the arm with the dynamo idle or running at very low speeds.

The entire dynamo output passes through a magnet winding and inside of this magnet winding is placed an iron plunger. This plunger is supported by a small cable that passes around a pulley attached to the sliding arm pivot, and as the plunger is drawn into the coil by increase of magnetism and amperage,

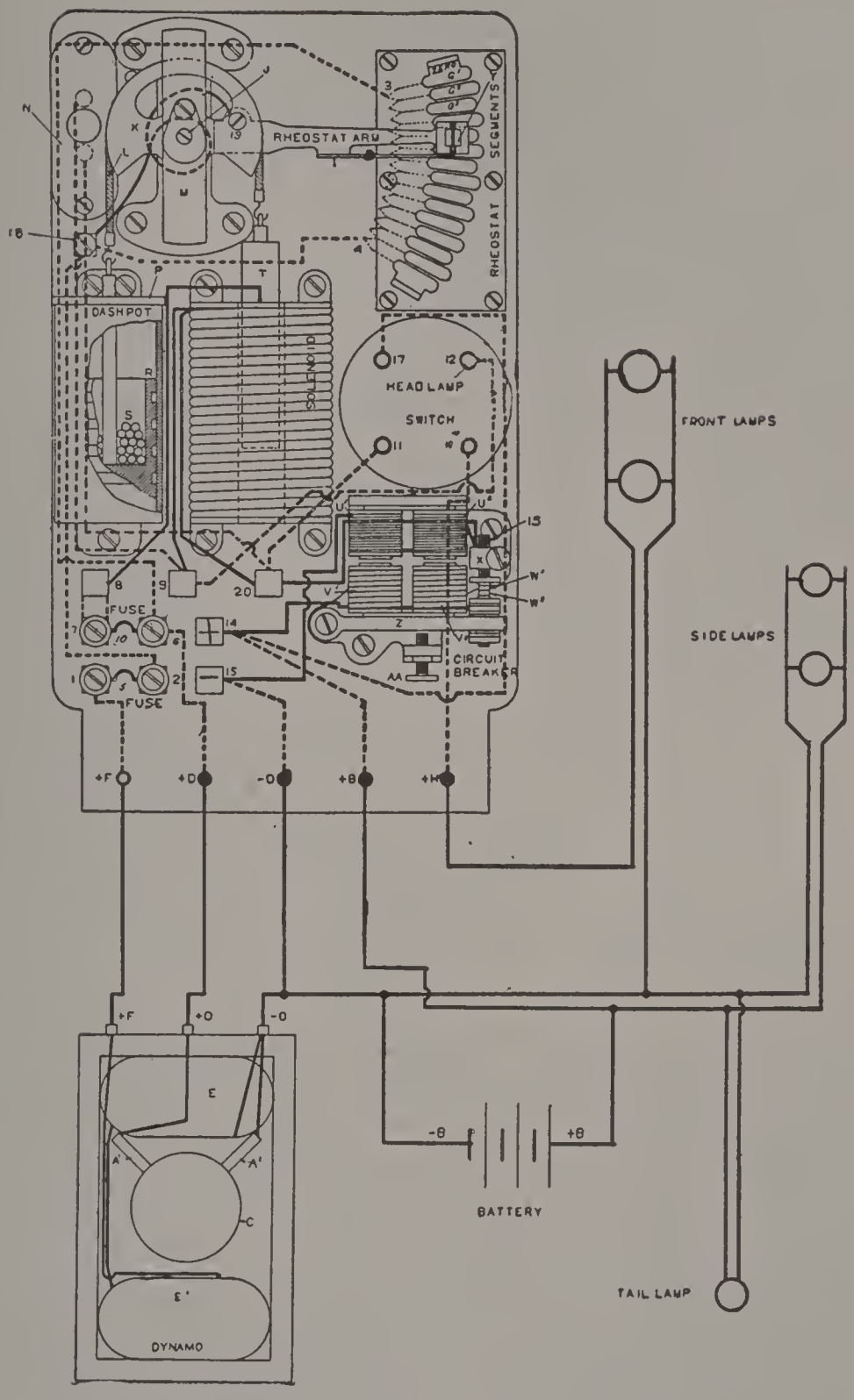


Figure 76.—Controller with Solenoid and Field Rheostat (Adlake).

the arm is caused to travel over the segments and thus place additional resistance in the field circuit. The dynamo output is altered by changing the weight carried by the plunger. Increasing this weight will raise the dynamo output, while decreasing it will lower the output.

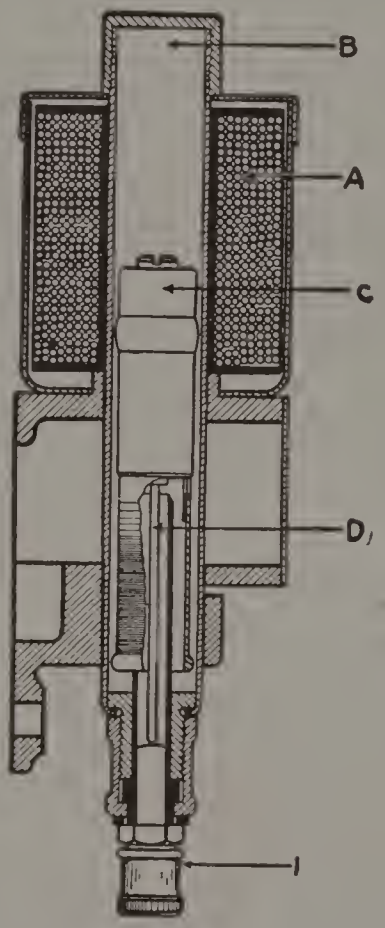


Figure 77.—Controller Using Mercury-Well Principle (Delco).

A—Magnet Winding.
B—Plunger Cylinder.
C—Plunger Core.
D—Plunger Rod in Mercury Well.
1—Field Circuit Connection.

(11) A number of Delco systems have been fitted with a regulator known as the "mercury well" type. See Figure 77. This regulator includes a tube made from insulating material and carrying a coil of resistance wire wound around it. The lower end of this coil of wire dips into a well, or pocket, in which

is carried a quantity of mercury. The field circuit is completed through the resistance wire and the mercury, one end of the field circuit attaching to the wire and the other end to the mercury well. With the dynamo idle or running at low speeds, the plunger tube drops down into the mercury so that the field current does not have to flow through a great length of the coil, but passes directly into the mercury and through the well with its comparatively small resistance.

Around the upper end of the tube is placed a magnet winding, and the upper end of the tube forms an iron plunger. The magnet winding is attached between the dynamo brushes, and with increase of dynamo voltage, the strength of the magnet winding is increased. This magnetism will finally lift the resistance tube so that a greater length of the wire is held up out of the mercury. The field current is reduced by flowing through this additional resistance, and the dynamo voltage is prevented from rising above a predetermined point. The voltage is adjusted by changing the resistance in the magnet circuit either by means of a small lever on the regulator or by placing a connecting link of high or low resistance between regulator and cut-out, a higher resistance allowing an increased voltage.

(12) A method of regulation rarely used has been employed with some of the older models of Deaco equipment. These dynamos carry permanent field magnets, and in connection with these magnets, have a set of shunt field coils. An electromagnet is carried underneath the arch of the permanent magnets, and by opening and closing contacts with increase of

dynamo output flowing around the magnet winding, the following action takes place:

At low dynamo speeds the shunt field windings assist the permanent magnets and a relatively high output is maintained. With increase of speed and voltage, the shunt field circuit is opened and the permanent magnets act alone, the loss of the field winding strength serving to counteract the increased speed. With a still further increase of speed, the circuit is completed through the shunt field windings, but with the current flowing in such a direction that the windings oppose the permanent magnets. At this time the field current flows through a length of resistance wire. At the highest dynamo speed the resistance is removed from the shunt field circuit and the full field strength opposes the magnetism of the permanent magnets. The steadily increasing dynamo speed is opposed more and more by the decrease in strength of the fields, and the output of the dynamo is held at practically a constant value.

(13) The voltage acting on the field circuits of a shunt wound dynamo is primarily determined by the speed of armature rotation. If this speed were to be kept constant, and at the same time the resistance through the outside circuits were to remain practically constant, the dynamo voltage would remain at the same point. This effect is secured in some systems, notably in a large number of Gray & Davis dynamos made previous to 1915. Dynamos of this make and with this type of regulation have also a compound field winding through the series coils of which the lamp current passes as described under (3) in this chapter.

The armature shaft is not connected directly with the engine, but is fastened instead to a framework that carries two friction shoes. See Figure 78. These shoes are held in contact with the inner surface of a cylindrical drum, or in some cases, the shoes are replaced with a flat disc and this disc is held in contact with a similar disc by the tension of adjustable springs. The drum, or the second disc, is attached to the dynamo drive shaft and as long as the two parts, shoes and drum or discs, are held together, the arma-

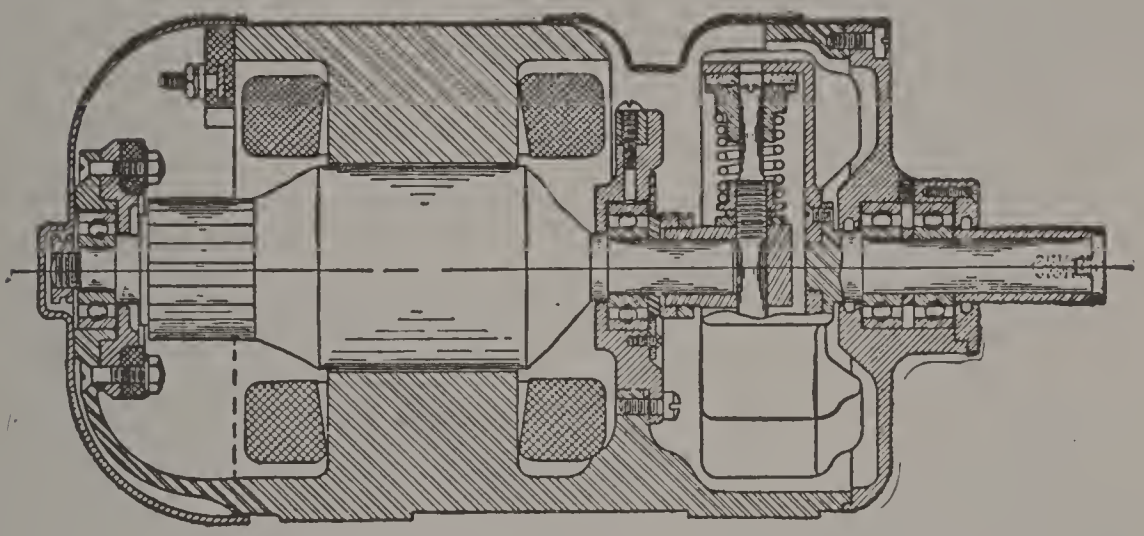


Fig. 78.—Friction Clutch for Limiting Dynamo Speed (Gray & Davis).

ture shaft will be driven at the same speed as the drive shaft. Therefore, as long as the two driving parts are together the dynamo speed will rise and fall in direct ratio to the engine speed. Two governor weights are fastened to the armature shaft and revolve with it. The arms carrying these weights are attached to the shoes or to the movable disc in such a way that when the weights are caused to fly apart by centrifugal force the shoes are drawn away from the drum or the discs are drawn apart. The driving parts

are normally held together by coiled springs, and when the pull of the rapidly revolving weights is sufficient to overcome the tension of these springs, the armature shaft is released from the driving shaft and the speed of the armature will not be increased above this point.

The dynamo voltage and output is changed by changing the tension on the governor spring or springs. Increasing the spring tension will cause the armature shaft to remain connected to the driving shaft until a higher speed is reached and the output will show a corresponding increase. Decreasing the

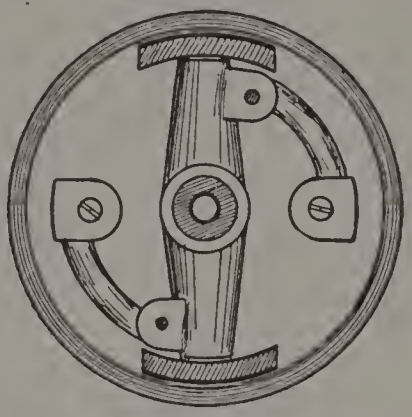


Figure 79.—Friction Clutch for Limiting Dynamo Speed (Auto-Lite).

spring tension will prevent the armature from revolving at such a high speed and the output will be reduced.

(14) A form of governor operating on the same principle as the one just described has been used with older models of Auto-Lite dynamos. See Figure 79. The governor consists of a drum fastened to the driving shaft and of two shoes, each one attached to a weight and held in contact with the drum by the tension of a spring. In this case the spring tension is

not changed, but dynamo output is altered by moving the weights on their supporting arms. The weights are held in place by screws, and as the weights are moved farther from the pivotal point of their respective arms, they produce a releasing effect at a lower speed and consequently reduce the dynamo output. Moving the weights in on the arms increases the dynamo voltage and output. Dynamos that are fitted with this form of regulation and of Auto-Lite make are fitted with permanent field magnets.

(15) One other application of the centrifugal governor has been used, this being the system applied to certain models of Vesta dynamos. These machines use permanent field magnets, and the regulator is carried at one end of the dynamo housing. The governor weights are attached to a sliding ring, and as this ring moves along its shaft under the action of the flying weights, it compresses an adjusting spring. Attached to the sliding ring is an arm whose outer end travels over a rheostat. This rheostat consists of a number of segments, the end one being disconnected from all wiring and each pair of the remaining segments carrying a coil of resistance wire between them. With the dynamo idle, or running at very low speeds, the end of the arm rests on the segment that has no connection. The charging circuit is attached to this arm, and when the end of the arm is on the disconnected segment, the dynamo is disconnected from the battery. This part of the governor acts as a cut-out.

As the arm travels over the segments with increase of armature speed and centrifugal force from the weights, a continually increasing number of resistance coils is inserted in the charging circuit and an excessive battery charge is thereby prevented. The

time of cutting in and out as well as the dynamo output is adjusted by changing the tension of the governor springs. There are two springs, one acting to regulate the time of cut-out action and the other being for output regulation.

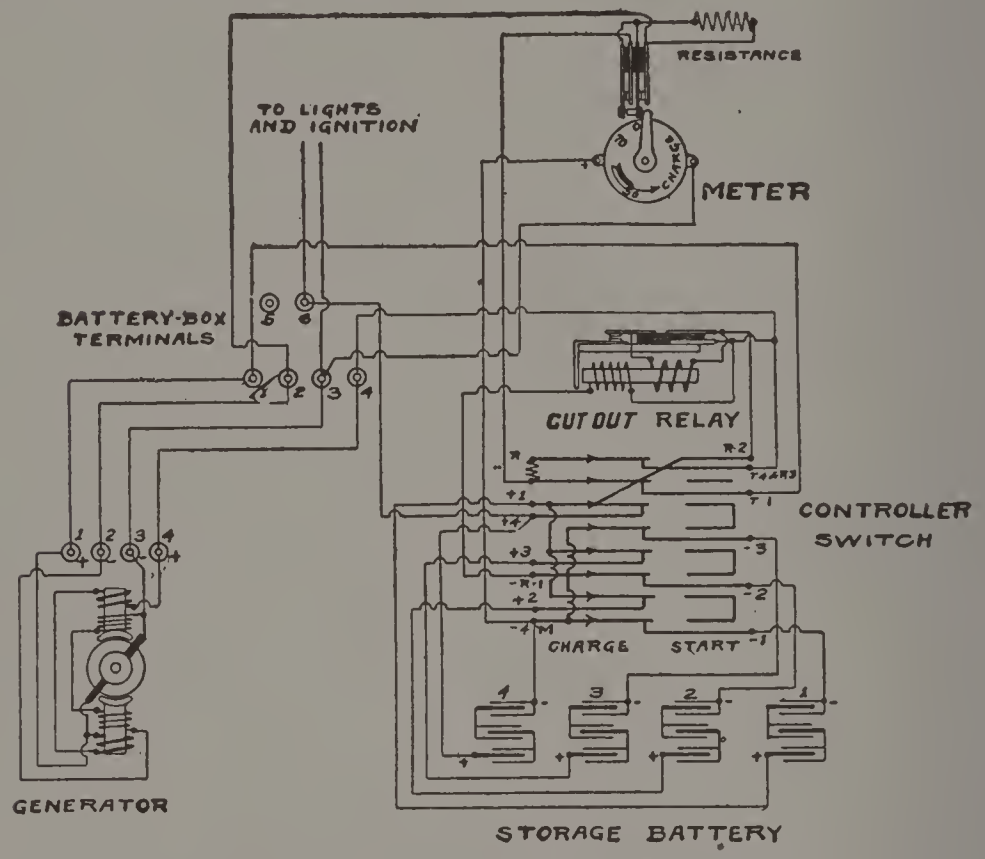


Figure 80.—Connections for Ampere-Hour Meter Regulator (Delco).

(16) The first Delco systems to be used during 1912 and 1913 were equipped with an ampere-hour meter that measured and indicated the number of ampere-hours that passed into or out of the battery. This meter, Figure 80, is attached in such a way that all of the current entering the battery from the dynamo causes an indicating hand to travel in a counter-clockwise direction, while all current leaving the battery for lighting, starting and other purposes causes the hand to travel around its dial in a clockwise direc-

tion. Carried in the meter case is a set of contact points through which the field current must pass, and movement of the meter past a certain position causes first one pair of contacts to open, and with further travel in the same direction during battery discharge, causes the other set of contacts to separate. With the first set of contacts open, the field current must pass through a length of resistance wire, thus reducing the field strength and charging current. When the second set of contacts open, the field circuit is opened altogether and further charge is stopped because there is practically no field strength.

As the battery continues to charge without a proportionate discharge the meter hand comes around to a point at which the first set of contacts will open. Should the use of the car go on without calling for any considerable discharge from the battery, the meter hand will finally travel to a position that will open the second set of contacts and the charge will be stopped. If now the battery current be used, the meter hand will revolve in the opposite direction and the second set of contacts will close. The dynamo will then start to generate current at a low rate because of the completion of the field circuit through the resistance wire. With further net discharge of the battery the first set of contacts will close and the dynamo charge will reach its full value. With this system in operation it is necessary to move the hand in the direction of discharge at intervals of about two weeks because of the fact that a storage battery must have a greater number of ampere-hours charge than discharge. The meter hand is held in place by a toothed joint, and by lifting it up, it may be reset to give the necessary additional charge.

It should be noted in connection with the adjustment of regulating devices and the consequent changing of dynamo outputs that this is necessary only under exceptional conditions. The adjustment made by the manufacturers of the car or of the electrical equipment is correct for that car under average conditions, and it should never be altered until the person doing the work is sure of reasons sufficient to warrant the change. It will usually be found that low dynamo outputs are due to lack of proper care in cleaning brushes and commutators, in keeping wire connections clean and tight and in keeping the battery clean and filled with pure water.

It is, however, possible that unusual conditions of service may call for a change in dynamo output. For instance, a car that is driven mostly at night with the lamps lighted may require that the dynamo have a greater output than for one that is driven under usual conditions. The addition of electrical accessories sufficient to make a load on the system greater than it was designed to handle is not a good reason for increasing dynamo output, and doing so under these conditions will usually result in permanent damage to the electrical equipment.

In some cases the output adjustment is rendered easy of use by the repairman or driver of the car and the makers may furnish instructions for altering the charge rate for different conditions. In other cases, and the number of these is increasing, the adjustment is made at the factory, and the parts are then sealed so that this adjustment cannot be changed without breaking the seals. In these cases, breakage of the seals will result in the maker's guarantee becoming void.

As a general rule the dynamo output should be greater in winter than in summer because of the lower efficiency of the battery and the greater use of the lamps and starter at this time. During a long tour it may be advisable to lower the charge rate or to stop the charge altogether, by short circuiting the dynamo terminals, by opening a touring switch, if one is provided, or by removing a field fuse.

Considering the various methods of regulation from the standpoint of adjustment, the following points should be noted: It is not practicable to alter the dynamo output when reversed series regulation is used and this advice applies equally well to machines having compound field windings. The remaining classes of inherent regulation may usually be adjusted; the third brush by changing the position of the brush, and the iron wire system by changing the size of the wire used.

It is seldom advisable to attempt to make changes in adjustment of magnetically controlled vibrators that act to insert and withdraw field resistance, and in fact these types are not always made with provisions for adjustment. Adjustment is provided on systems that use carbon field resistance and the methods of adjustment have already been considered.

The dynamo output of the system that uses an ampere-hour meter is not directly adjustable, although the total net battery charge may be increased by moving the hand so that the contacts are not separated at such frequent intervals. The adjustment of the system using the rheostat operated by the plunger and coil is provided for by changing the weight in the plunger while a certain adjustment may be secured with the mercury well regulator by altering the resistance in series with the magnet coil.

Regulation depending on the action of centrifugal governors is always provided with means of adjustment. It should be borne in mind that these adjustments are very delicate and the slightest possible change in spring tension or weight position will have a considerable effect on the dynamo output.

Temperature Control.—In order to allow the dynamo to furnish a comparatively high rate of charge during cold weather and at all times while the dynamo itself is cold the Remy Electric Company has introduced an auxiliary form of current regulating device which is acted upon by the dynamo temperature.

A dynamo becomes heated to a degree proportionate to the amount of current flowing or the amount being generated. A low output with low amperage flowing to the battery allows the wiring to remain at normal temperatures, while higher amperage causes heat to be generated because of resistance of the wiring. This change of temperature is made to operate a thermostat which is carried in the dynamo.

The thermostat bracket carries a small coil of resistance wire and a blade made from a strip of spring brass welded to a strip of nickel steel. Due to the greater expansion of the brass this combination will bend when heated. Mounted on the base is one of a pair of silver contact points, the other contact being carried by the blade. The points are held together by the spring tension of the blade itself as long as the combination remains at normal temperatures. When the heat within the dynamo reaches approximately 175° Fahrenheit the bending of the blade causes the contacts to separate.

The connection of the thermostat in the circuit is shown in Figure 80a. The resistance coil is connected

between the parts which carry the contact points. The moving blade is connected with the line leading to one of the dynamo brushes, while the base which carries the stationary contact is connected with the line leading to the field windings. With the dynamo cool the contacts are together and the field current flows at its full value from the dynamo brush through the closed

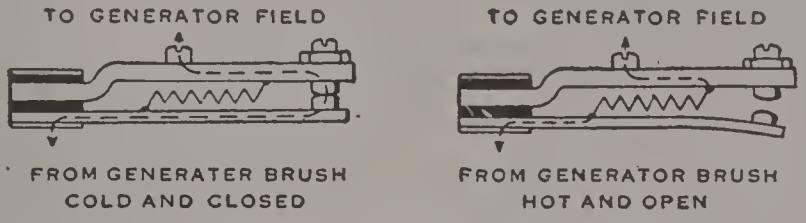


Figure 80a.—Thermostatic Control.

contacts and to the field, the dynamo giving its normal output. Generation of heat finally causes the contacts to separate and the field current must then take the path through the resistance to the fields. This interposing of the resistance reduces the flow of field current and the output of the dynamo is cut about one-third until the parts again cool off and allow the contacts to close.

Adjustment or repair of the thermostat should rarely be attempted, it being more satisfactory to install a new unit in case of trouble. If the screw by which the field line is attached should be turned, no weight or downward pressure should be put on the screwdriver because the thermostat frame may be bent. The contact points should never be forced apart as the blade might be sprung and the action rendered incorrect. Should the resistance coil be broken or burned out the dynamo will generate while cold and as long as the points remain in contact, but as soon as heat develops the points will separate and prevent any flow of field current or any output from the dynamo

until it cools sufficiently for the points to again close. Such a condition as that just described will cause severe burning of the contacts and they may possibly weld together. Should the contacts remain closed the dynamo will give its high output continuously and may thereby cause damage to the battery and the dynamo itself. A burned out resistance indicates trouble such as a loose connection, a corroded battery terminal or an open circuit in the charging lines.

CHAPTER VI

DRIVE METHODS AND STARTING SWITCHES

With the exception of the type of equipment which mounts the motor-dynamo directly on the engine crankshaft, all starting motors and some charging dynamos require a method of drive that allows their armature speed to exceed the speed of the engine crankshaft. This reduction is effected in the connec-

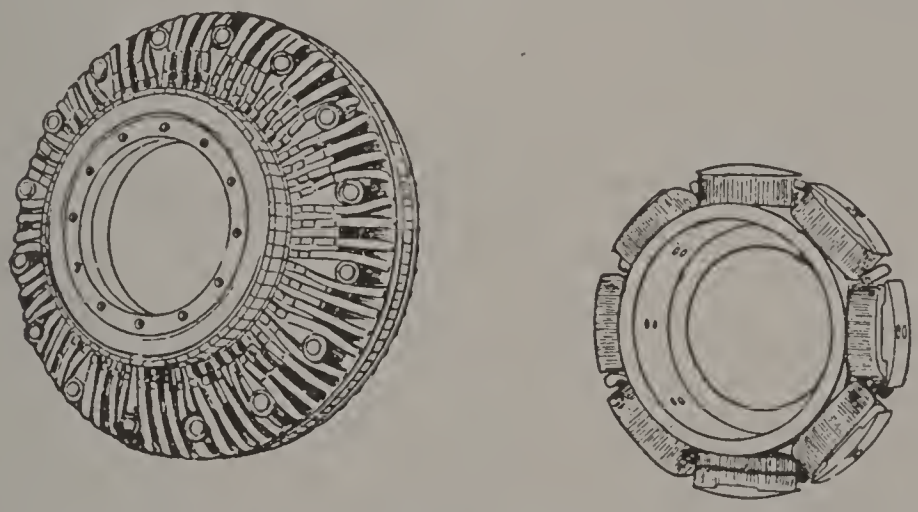


Figure 81.—External Armature and Fields for Motor-Dynamo (U. S. L.).

tions between engine and electric unit and may take any one of a wide variety of forms.

Mechanically speaking, the simplest possible drive is that used by the U. S. L. equipment. The electric unit, Figure 81, is a large size ring armature type of motor-dynamo having the armature fastened securely to the engine crankshaft. In some of the older types the armature revolves inside of the field coils, while

in later models the armature diameter is great enough so that it is carried outside of the fields. In all cases the armature revolves and the fields are stationary. This machine acts as a compound-wound starting motor when the starting switch is closed. When the engine has started and is running under its own power the speed of the motor-dynamo armature becomes great enough to generate a voltage in excess of that of the battery, the electromagnetic cut-out closes and battery charging commences. The motor-dynamo is carried inside of the flywheel housing and the starting switch may be mounted on this housing or at some other point on the car. The regulating device and cut-out, or else a separate electromagnetic cut-out, will be found on the cowl or dash of the car.

A very common method of drive for either dynamo, motor or motor-dynamo is through straight spur or helical gearing from the engine timing or ignition drive gearing. In this case the electrical unit is mounted and driven in much the same way as employed for magneto drives and in many cases is driven by the same shaft that drives the magneto. The water pump shaft, when a pump is used, forms a convenient method of drive for the electric machine and this shaft is often used by mounting the motor or dynamo at the end of an extension from the shaft passing through the pump.

A satisfactory connection and a simple application is secured by connecting the electric units to the engine crankshaft by means of a chain of either the roller or silent type. The crankshaft sprocket may be at either end of the engine, although the front or starting crank end is usually used. In some cases the drive chain will be enclosed and possibly lubricated

from the timing gear or crankcase compartment of the engine. In other applications the chains remain exposed and in plain sight.

Chain drive, gear drive or direct drive on the crankshaft may be utilized for either dynamo or motor because these types are well suited to carry loads as great as those imposed in engine starting and provide a positive connection. Drive methods that depend on friction between two surfaces can only be used for dynamo work because of the fact that they would not have sufficient surface available on an automobile to carry the power delivered by the motor in cranking. Belt drives have been used and are now used by a limited number of makers, and are satisfactory in all ways as long as the belt is kept tight enough to prevent excessive slippage and as long as both belt and pulley surfaces are kept clean and smooth. Dynamos have also been driven by means of a friction clutch, this application being made with the Entz motor-dynamo used on some models of White cars. With such a clutch in use sudden acceleration of engine speed does not place severe strains on the motor-dynamo drive parts.

A distinctive form of motor-dynamo drive has been used with a great many applications of the Delco system (Figure 82), this method allowing the motor-dynamo armature to run at a greater speed during engine starting than while generating current, yet providing a positive drive in each case. The single armature of the motor-dynamo has an extended shaft at each end. At the rear end this shaft extension carries one of a train of gears that mesh with teeth cut on the rim of the flywheel. With this flywheel gearing in mesh and with the motor-dynamo operating as a

starting motor, the gear reduction is about twenty to one. The front end extension of the armature shaft is driven from another shaft, which is in turn driven

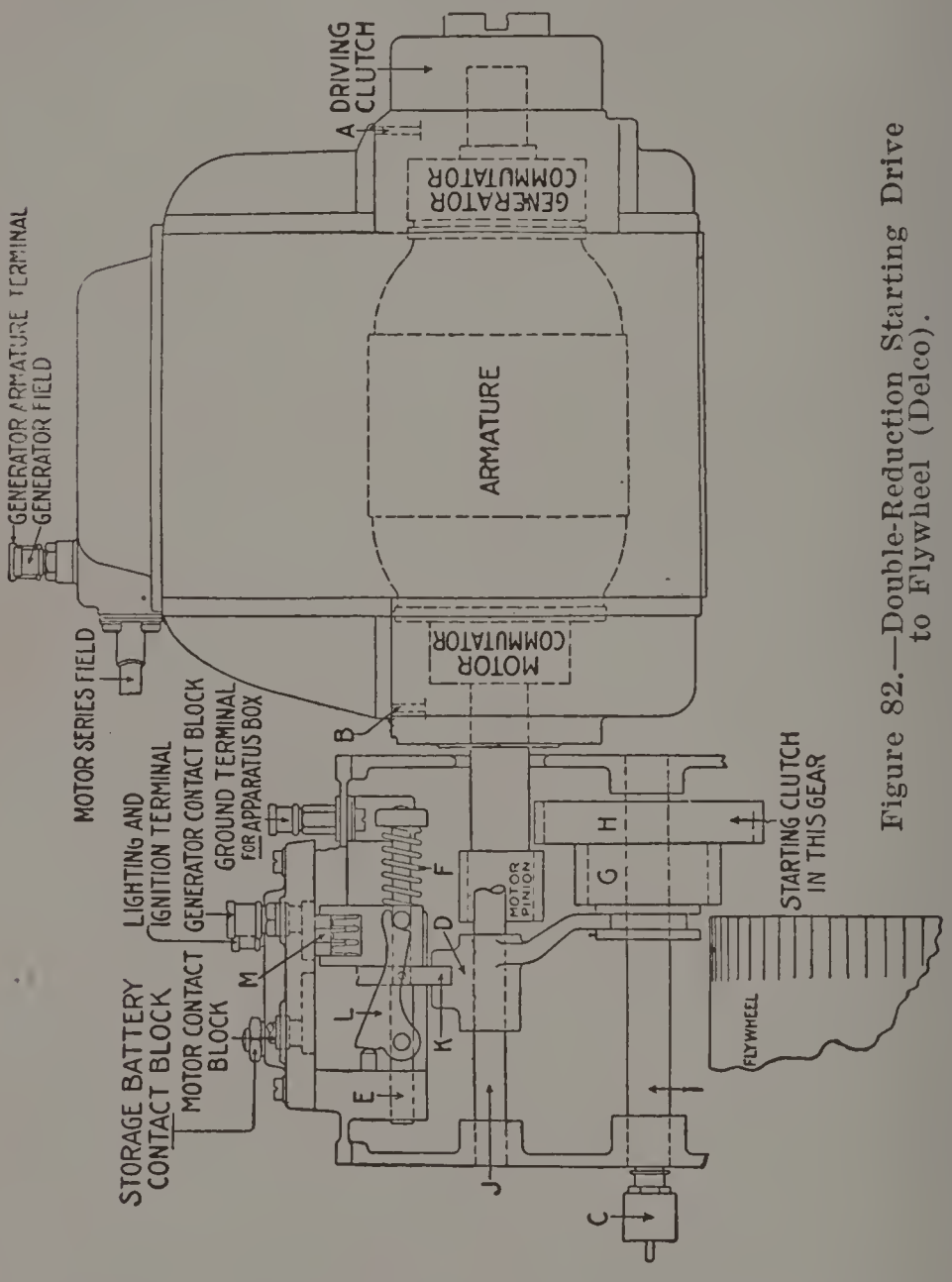


Figure 82.—Double-Reduction Starting Drive to Flywheel (Delco).

A, B, C—Lubrication.
D—Gear Shifting Yoke.
E—Switch Rod.
F—Switch Spring.
G—Flywheel Drive Gear.
H—Intermediate Gear.
J—Shifting Rod.
K—Spring Trip Collar.
L—Switch Latch.
M—Switch Terminals.

from the front end of the engine crankshaft by means of gearing or chains. The connection from the front end of the armature shaft to the driving shaft is made through an overrunning or one-way clutch. This

shaft and clutch will drive the armature shaft between two and one-half and three times as fast as the engine crankshaft runs, and as long as the armature shaft has no tendency to run faster under its power as a starting motor, the clutch will hold. Whenever the battery current is sent through the motor-dynamo, the armature shaft begins to turn and the overrunning clutch releases so that the armature shaft runs at the starting speed.

DRIVE RATIOS

Large dynamo output may be secured in either of two ways, high speed or large size. It is manifestly not practical or desirable to use dynamos of large size on automobiles because of the excessive weight and greater cost. The alternative of comparatively high speed is therefore resorted to. Dynamos generally are operated at from one to four times engine speed, the most common ratios lying between two to one and three to one. With a rear axle gear ratio of four to one and with thirty-four-inch diameter road wheels in use, the engine crankshaft will turn about forty revolutions per minute for each mile per hour of car speed. Therefore, at a car speed of fifteen miles per hour, the crankshaft will be revolving at about 600 revolutions per minute; at a car speed of twenty miles per hour, the crankshaft speed will be about 800 revolutions per minute, and so on for various car speeds. The types of dynamos in general use do not deliver their maximum or rated amperage at armature speeds much below twelve to fifteen hundred revolutions per minute, and it is desirable that this maximum output take place at driving speeds of about twenty miles per hour. It will be seen that in order to drive the armature at

the required speed with the crankshaft running at about 800 revolutions per minute, a ratio of one and one-half or two to one will be required.

The conditions governing the selection of a starting motor drive ratio are the power that the motor will deliver at its armature shaft, the power required to start the engine crankshaft and engine parts in motion, and the power required to keep the crankshaft rotating at a speed sufficiently high to cause good carburetion and ignition. The engine conditions, in turn, depend on the bore and stroke of the cylinders, on the number of cylinders and on the excellence of design and workmanship in the engine. The power delivered by the starting motor depends on the amperage and voltage of the current flowing through it, on its speed of rotation, and on the excellence of workmanship and material. Power required by, or delivered from, rotating shafts is usually measured in foot-pounds, one foot-pound being the power required to lift a weight of one pound through a distance of one foot.

From three to four times as much effort is required to start an average engine from rest as is required to keep it in motion after being started, and the maximum power that the motor will deliver must be selected with the starting torque in mind. The word "torque" means a twisting or turning force, and as the powers being dealt with here are of this class, the measurements can most conveniently be given in this way.

The number of foot pounds torque required by several commonly found sizes of engine is given in the following table and will give a good idea of the work that the starting motor is called upon to do.

Bore	Stroke	No. of Cylinders	Running Torque	Starting Torque
3¾	4	4	20	82
3¾	6¾	4	34	125
3¼	4½	6	25	95
3½	5¼	6	32	120
3¾	5¼	6	40	140
4	5½	6	43	155
5	7	6	88	245
3¼	5¼	8	35	130
3	5	12	45	156

While the engine specifications selected in the table are those of well-known makes of cars, this has been done only for the comparative value of the figures, and does not necessarily represent the exact conditions that would obtain with a certain engine of a given make because of the variables in manufacture.

Depending on the size and design, typical starting motors will deliver from three to eleven foot-pounds torque with current flow between two and three hundred amperes. Taking an average case of a starting motor capable of delivering six foot-pounds torque, it will be seen that for the medium-size engines listed in the table, the gearing must provide a reduction of from seventeen to one up to twenty-five to one in order that this six pounds torque at the armature shaft may be multiplied to produce the 100 to 150 pounds torque required to start these engines from rest. It will be found that a majority of starting motors in use are provided with reductions that fall between these two limits.

From the running torques given in the table it will

be seen that the average engines will require from twenty-five to forty-five foot-pounds of torque to keep them in motion. If a gear reduction of twenty to one is selected, the torque required for running will be divided by this reduction so that the starting motor will only have to deliver between one and one-quarter and two and one-quarter foot-pounds at the armature shaft after the engine has been started. The amperage required to accomplish this will be much less than that called for in starting from rest, and with starting motors of usual design will range from sixty to one hundred and fifty amperes. This amperage will allow the starting motors to attain armature shaft speeds of from 1200 to 3000 revolutions per minute. These speeds, with the reduction of twenty to one, will give a running speed for the engine crankshaft of from sixty to one hundred and fifty revolutions per minute. The speed required will vary with different engines, and it will be necessary to select a starting motor that will attain the required speed through the gear reduction in use while developing sufficient power to keep the engine in motion at that speed. Crankshaft speeds between seventy-five and one hundred and fifty revolutions per minute are satisfactory in practically all cases, although engines are driven at higher speeds in many installations.

The drive ratios selected for use with motor-dynamos do not depend on the same factors as those for separate units, because of the fact that the machine must usually operate at the same ratio for generating current as for starting the engine. As a general rule the armature shaft is made to revolve from two and one-half to five times as fast as the crankshaft. The power of the motor-dynamo as a starting motor must,

therefore, be considerably greater for a given speed than that of separate units.

Various combinations of chains and gearing are used to obtain the necessary ratio of speed between the starting motor armature and the engine crankshaft. In the case of installations driving to the crankshaft direct, some form of double reduction will generally be used with separate starting motors, because in order to secure a ratio as great as twenty to one, or even ten to one, with a single reduction, the size of the driven gear or sprocket would be excessive. In order to use a single pair of gears or sprockets and obtain a ratio of twenty to one with an armature shaft gear or sprocket one and one-half inches in diameter, the driven member would have to be twenty times this diameter, or thirty inches, which would, of course, be impossible to use. To overcome this difficulty, a double reduction system is used with which a part of the total reduction is taken care of in each set of gears, or part in a set of gears and the remainder by chains with sprockets of different sizes.

When it is realized that two separate reductions of four to one will give a total reduction of sixteen to one, the problem is seen to be simple of solution, and the drive parts will be of very moderate diameter and still secure the desired ratio of drive. (See Figure 83.) When such a double reduction is used with chains for the final drive to the crankshaft, the primary reduction gearing is usually carried on or in the starting motor housing, one side being connected to the armature shaft and the other side to the sprocket on the outside of the housing to which the chain attaches.

Double reduction systems may consist of sets of

spur gears very similar to those used in the change speed gearing of the car, and in some applications, notably older models of the Wagner systems, planetary forms of gearing have been used successfully. The ratio that corresponds to low speed in driving a car is then used for starting purposes, while the direct drive is used when the machine acts as a dynamo—the equipment in question being a single armature motor-dynamo. A number of makers have used a small spur gear running inside of a large ring gear

Figure 83.—Single Reduction (Left) and Double Reduction (Right) Giving Same Drive Ratio.

with internal teeth. This method gives a great reduction in speed within a small overall space.

A single reduction is oftentimes used when the gear on the armature shaft drives to teeth cut on the rim of the flywheel. With a flywheel seventeen inches in diameter and an armature shaft gear one and one-half inches in diameter, the reduction will be approximately twelve to one, which will answer in almost all cases. Even with flywheel gearing the double reduction system is often used, the primary reduction being much the smaller of the two and taking place in gearing carried in or near the starting motor housing. This is shown in Figure 82.

While the drive to the flywheel or a drive to the engine crankshaft is the method usually employed for the starting motor, other systems are also in use. In the case of machines known as "double-deck," with the starting motor mounted above, below or at one side of the dynamo, the drive from the starting motor armature shaft to the main drive shaft, through which the engine drives the dynamo, provides a reduction

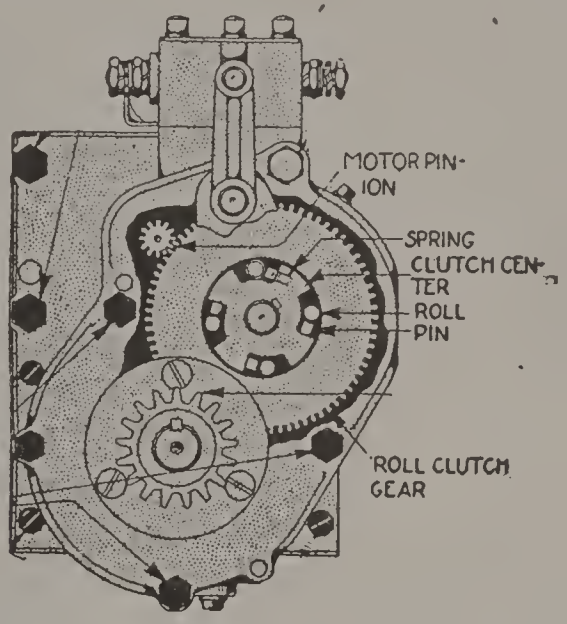


Figure 84.—Drive Parts for Double-Deck Motor and Dynamo (Gray & Davis).

that allows the starting motor to operate at six or more times the speed of the dynamo shaft, which, with the generally found dynamo reduction of two to one up to three to one, will provide a total reduction of from twelve up to twenty to one. (See Figure 84.)

The starting motor does not always drive direct to either the engine crankshaft or to the flywheel, but may be so connected that it drives first into the transmission or clutch shaft. With the clutch engaged, the countershaft in a sliding gear transmission will revolve

and be positively connected to the engine whether the gearing is in any one of the forward or reverse speeds or is in neutral. In some applications the starting motor is carried on the transmission housing or alongside of the housing, and drives through gearing to the transmission countershaft, thence through the clutch to the engine. This method allows of locating the starting motor in a convenient place when the room under the engine hood is so limited that mounting there would prove difficult.

Another method of starter drive is that found with a worm gear drive from the starting motor to the clutch shaft between the clutch or flywheel and the transmission housing. By placing the starting motor transversely across the length of the car, a worm fitted to its armature shaft may be made to drive a worm gear fitted to the clutch shaft, and inasmuch as worm gearing may be built to give a very great reduction in speed, a suitable drive is secured by means of a single reduction.

DRIVE METHODS

In order to allow separate starting motors to drive the engine during cranking and then to be released so that they are not driven at excessive speeds by the engine, a number of exceedingly ingenious devices have been used. It is not uncommon for the gasoline engine to operate at crankshaft speeds as high as 2000 revolutions per minute. With a positive connection between starting motor and engine, and a gear reduction of twenty to one, this would cause the starting motor armature to revolve at 40,000 revolutions per minute, which is, of course, impossible, because the centrifugal force acting on the

armature would destroy the motor long before any such speed could be attained, even were the engine capable of furnishing sufficient power to do the work.

Bendix Screw.—A very commonly used system is that known as the Bendix drive or inertia pinion (Figure 85). By this method the armature shaft gear is automatically meshed with teeth on the flywheel as soon as the motor armature shaft starts to revolve, and then, as soon as the engine speed is high enough for the flywheel rim speed to exceed that of

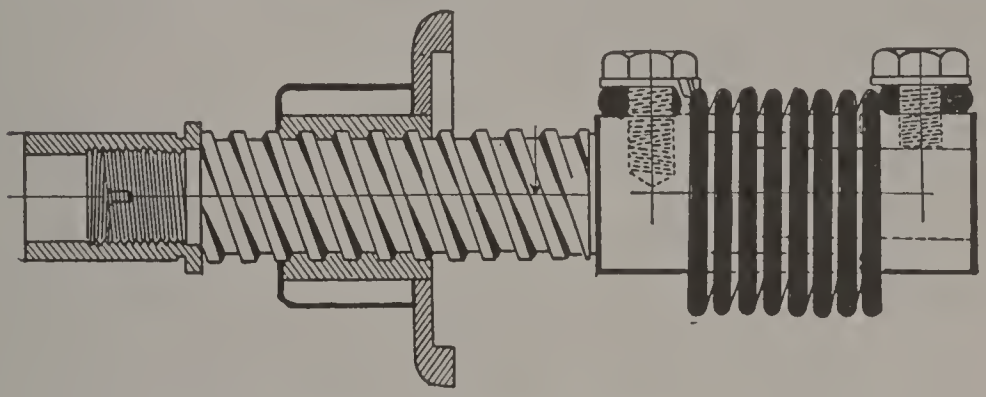


Figure 85.—Bendix Drive; Screw, Spring and Pinion.

the armature shaft gear, the gear is instantly thrown out of mesh. Surrounding the extended armature shaft is a sleeve free to move on the shaft but connected to the shaft through a coiled spring having one end fastened to the armature shaft and the other end fastened to the sleeve. On the outside of this sleeve is cut a coarse multiple screw thread, and a small gear with a correspondingly threaded hub is carried by the sleeve. As the shaft is turned, the gear will travel back and forth along the threaded sleeve just as a nut would travel along a bolt if the bolt were turned while the nut remained stationary. The starting motor is mounted in such a position that the sleeve gear is in mesh with teeth on the flywheel rim

when it is at one end of the threads, and is completely out of mesh with the flywheel when at the other end of the threads.

With the engine and starting motor idle, the small gear is out of mesh with the flywheel. Just as soon as current is sent through the motor the armature shaft turns and, through the coiled spring, causes the sleeve to turn. On one side of the gear is a weighted flange, and because of this weight the gear does not commence to revolve at once, but rather travels along the threads of the screw on the sleeve. This action brings the gear in mesh with the teeth on the flywheel either instantly, or, if the teeth meet end-on and do not slide into mesh, the coiled spring allows the sleeve to turn on the armature shaft enough to bring the teeth into position for meshing.

When the small gear has traveled far enough on the threaded sleeve to be in full mesh with the flywheel teeth, one side of its hub has come against a shoulder on the sleeve and it can travel no farther. The gear must then revolve with the sleeve, and because of the resistance of the flywheel to motion, the spring coils tighter still. When the spring is tightly coiled, the full power of the starting motor, together with the power stored in the coiled spring, acts to place the flywheel in motion, and the engine is cranked by the starting motor until it starts and runs on its own power.

As soon as the engine starts, the speed of the rim of the flywheel causes the small gear to revolve much faster than the starting motor has been driving it, and because it travels faster than the motor shaft and sleeve, it begins to travel along the threads in a direction that takes it out of mesh with the fly-

wheel teeth. This change of direction is brought about because when the motor first started, the armature shaft and sleeve traveled faster than the small gear, while now the small gear is traveling faster than the armature shaft and sleeve. This action sends the gear out of mesh without causing the starting motor to attain any excessive speed. Should the starting switch be again closed with the engine running, the small gear will travel toward the flywheel and strike the rapidly turning teeth on the flywheel, and its speed will thereby be increased to such an extent that it again travels away from the flywheel. The weight on one side of the small gear that acted to prevent the gear from revolving with the threaded sleeve now performs another important function by making the gear bind on the threads through the overbalancing action of the weight on one side. This binding prevents the gear from again meshing with the flywheel teeth.

Overrunning Clutch.—In a large number of systems the starting motor drives the engine through an overrunning clutch that will allow the starting motor to drive the engine shaft as fast as it is capable of doing, but will allow the clutch to release whenever the engine tends to drive the starting motor. The principle involved is similar to that used in the bicycle coaster brake in which the rider (represented by the starting motor) might pedal the bicycle as fast as he possibly could, but with which no speed of the bicycle (represented by the engine) could cause the rider to pedal faster. In fact, the rider could stop pedaling altogether and allow the bicycle to run, just as the starting motor can come to rest and allow the engine to run.

The construction of an overrunning clutch is shown in Figure 86. The clutch consists of two principal parts, the outer ring *A* and the clutch center *B*.

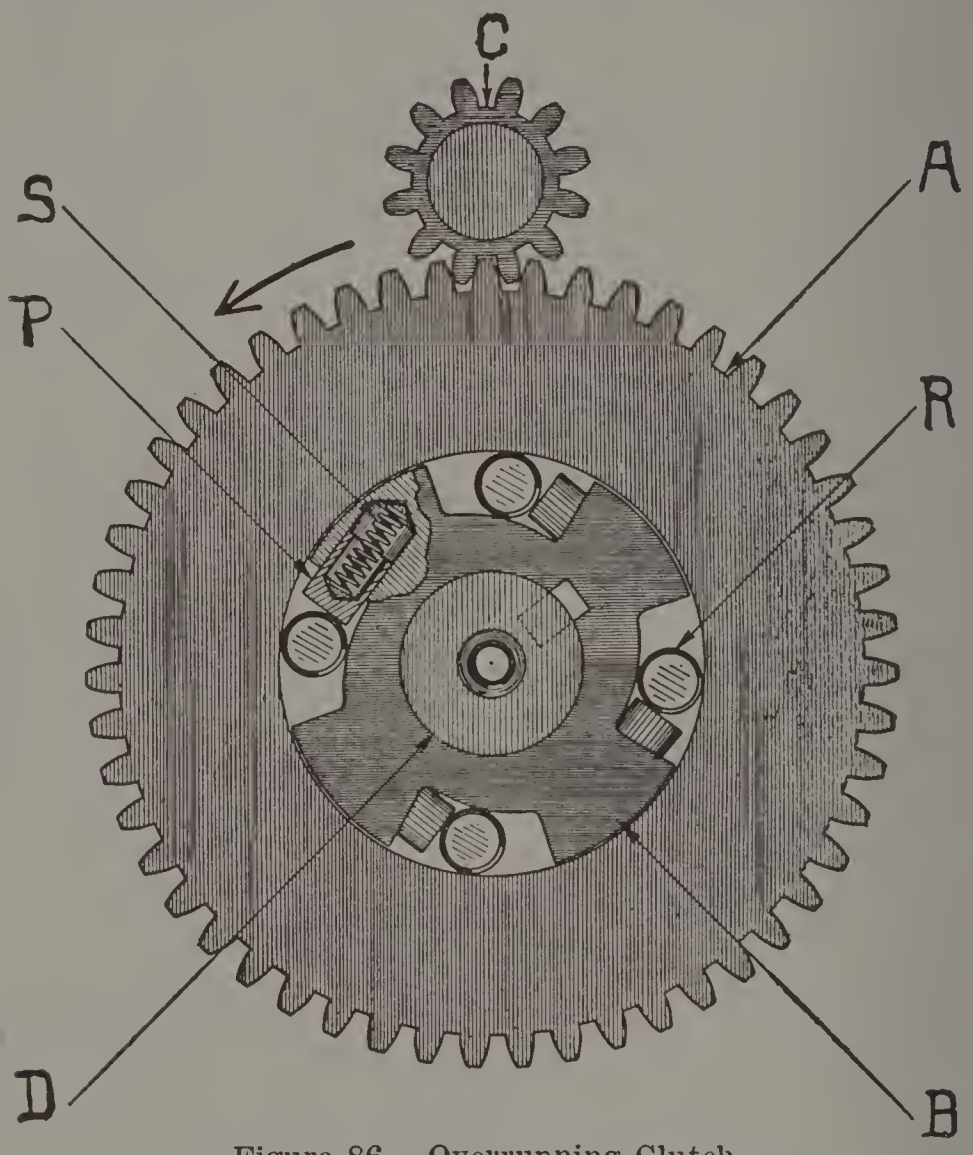


Figure 86.—Overrunning Clutch.

A—Driving Ring.
B—Inner Member.
C—Driving Pinion.
D—Driven Shaft.
P—Plunger.
R—Roller.
S—Plunger Spring.

The outside circumference of the ring *A* carries gear or chain teeth or a drive shaft, and is driven from the starting motor. In the construction shown, the starting motor drives the ring in the direction of the

arrow. At several points around the inner part of the clutch are slots in which rollers are placed. The roller is continually pressed against one end of the slot by the small plunger and spring, and it will be seen that rotation of the outer ring in the direction of the arrow will wedge the rollers between the ring and the center part of the clutch. With the rollers thus tightly binding the two parts together, the inner part will be rotated by the ring and in the same direction as that of the ring. The center part of the clutch is fastened to the shafting or gearing that cranks the engine.

With the power of the starting motor applied to the pinion *C*, the outer ring and center section will turn together just as soon as the rollers lock in place. The locking is practically instantaneous, so that cranking commences at once. The starting motor will continue to revolve the engine crankshaft until the ignition takes place and starts the engine under its own power. The engine will now drive the center of the clutch in the same direction as during the cranking operation, but, of course, at a much greater speed. The center part of the clutch now rotates much faster than the ring, and, in fact, the ring and starting motor can stop entirely because of the fact that rotation of the center part in the direction of the arrow tends to roll the rollers back toward the plunger and spring end of the slot, thereby allowing clearance and release of the wedging action between the two parts of the clutch. No amount of power applied to the center of the clutch so that it rotates in the direction of the arrows will cause the rollers to wedge, and the engine can increase in speed without any effect on the starting motor.

Rushmore Starting Drive.—A novel system of gear meshing is shown in Figure 87, this being the method applied to Rushmore and Bosch-Rushmore systems. In the idle position shown at *1*, the armature of the starting motor is held out of line with the pole pieces by the coiled spring *S*. On the opposite end of the armature shaft is carried the small spur pinion which will mesh with the ring gear *F* on the flywheel. The

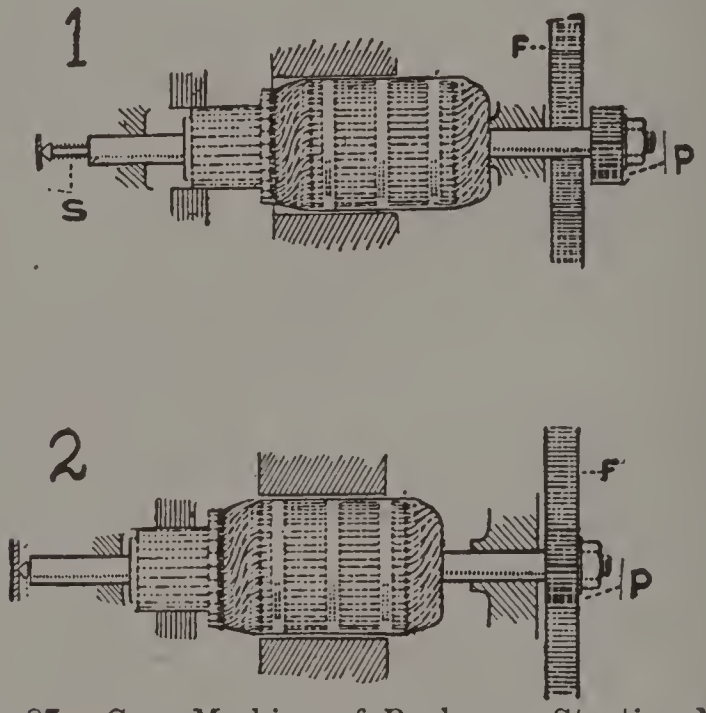


Figure 87.—Gear Meshing of Rushmore Starting Motor.

starting switch has two active contacts, which are made, one after the other, when the switch button or handle is moved. On the first contact the battery current flows through the fields and causes their cores and pole pieces to become strong electromagnets which act on the iron of the armature core to draw the armature with its shaft and the spur pinion quickly and powerfully to the left, thereby meshing the pinion with the flywheel gear. During this first contact a resistance is in the starting motor circuit so that but

a part of the full battery current can flow, and most of this current passes through the fields only, because of a low resistance by-pass for the armature current. The small flow through the armature causes its shaft and the pinion to rotate slowly so that the meshing of the gears will be accomplished without trouble. The pause on this first switch contact is just long enough to allow gear meshing, and then the full battery voltage and current is applied to the starting motor through the second contact, which cuts out the resistance and armature current by-pass. Cranking then takes place, and as soon as the engine takes up its cycle of operation, the flywheel gear rotates the small pinion at a high rate of speed. This high speed causes the motor to become momentarily a dynamo, with the result that at the moment when it generates battery voltage, there is no further flow of battery current through the motor. With no flow in either direction, the fields are demagnetized and the tension of the coiled spring throws the gears out of mesh. Thereafter, the small flow of current that would be required to keep the armature in motion, should the starting switch remain closed, is not sufficient to draw the armature endwise and mesh the gears again.

Westinghouse Magnetic Gear Shifts.—In addition to a mechanically operated system and other applications using the Bendix screw, Westinghouse equipment has been furnished with gear-shifting devices and starting switches operated by powerful electromagnets or solenoids (Figure 88). Passing through the starting motor armature shaft is a sliding rod which carries the spur pinion for flywheel meshing at one end and the core of a solenoid winding at the other. This rod is free to slide endwise, but must

turn with the armature shaft. In series with the starting motor circuit is the winding of the solenoid, and when the current for the starting motor passes through the winding the core is pulled back, with the result that the spur pinion, which has helically cut teeth, is meshed with the flywheel gearing. The gears are normally held out of mesh by a coiled spring, and when the pull necessary to start the engine is no

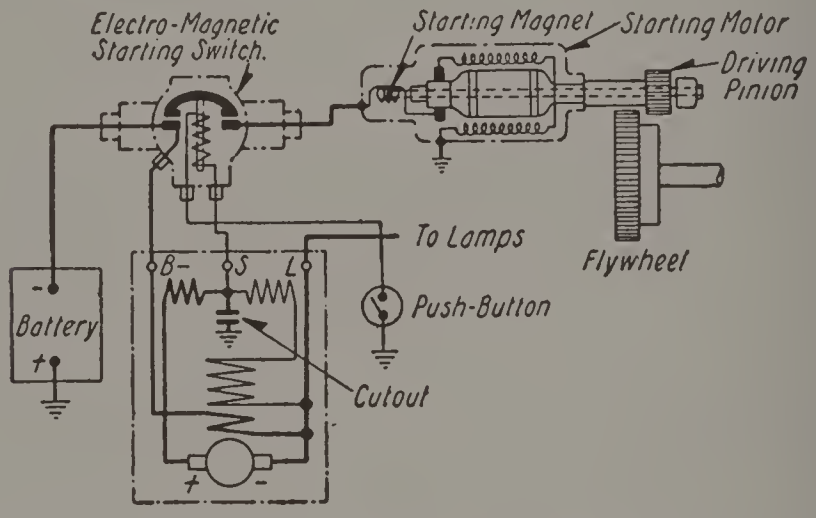


Figure 88.—Magnetic Starting-Gear Meshing System (Westinghouse).

longer required, the solenoid is demagnetized to such an extent that this spring pulls the gears out of mesh.

Double Reduction Systems.—A system of gear-meshing which has been very generally used with slight modifications by a number of makers is illustrated in Figure 89. The starting motor *M* has its armature shaft keyed and extended at *D*. The pinion *P* may slide along this shaft, but turns with it because of the squared construction. Pulling the rod *R* in the direction of the arrow will slide the pinion *P* into mesh with the flywheel ring gear *F* by means of the yoke *Y*. At the same time that the gears are fully meshed, the starting switch contact piece will have

closed the circuit between the contacts *S*, being moved by the arm *A*. The starting motor will then crank the engine in the usual way. An overrunning clutch is usually incorporated in the starting motor housing or in an intermediate gear between armature shaft and the pinion *P*.

In case the gear teeth should met end on, they would not mesh, and the following action would take place:

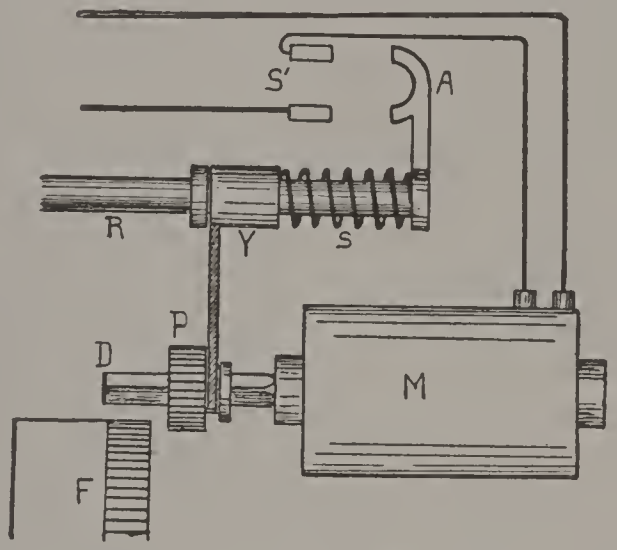


Figure 89.—Starting Drive with Spring Release.

A—Moving Contact of Switch.
D—Motor Armature Shaft.
F—Flywheel.
M—Starting Motor.
P—Motor Pinion.
R—Starting Pedal Rod.
S—Release Spring for Pinion Yoke.
S'—Switch Contacts.
Y—Gear Shifting Yoke.

The rod *R* is free to slide through the upper end of the yoke *Y*, except for the action of the coiled spring *S*, which holds the yoke against the collar shown on *R* and just at the left of *Y*. If the rod is pulled, the pinion *P* will first come up against the flywheel gear *F*, and then if *P* and *D* can move no farther, the coiled spring will be compressed against *Y*. Because of the fact that the rod *R* is moving regardless of the yoke, the arm *A* will cause the contact piece of the starting switch to close the circuit and the

starting motor will commence to revolve. The smallest part of a revolution of the armature shaft will bring the gear teeth into meshing position, and the tension that has been placed on the spring *S* by the continued movement of the rod *R* will instantly snap the pinion into full mesh with the flywheel gear, and cranking will take place.

In the system just described, power is not applied to the starting gearing in any way until the gears are

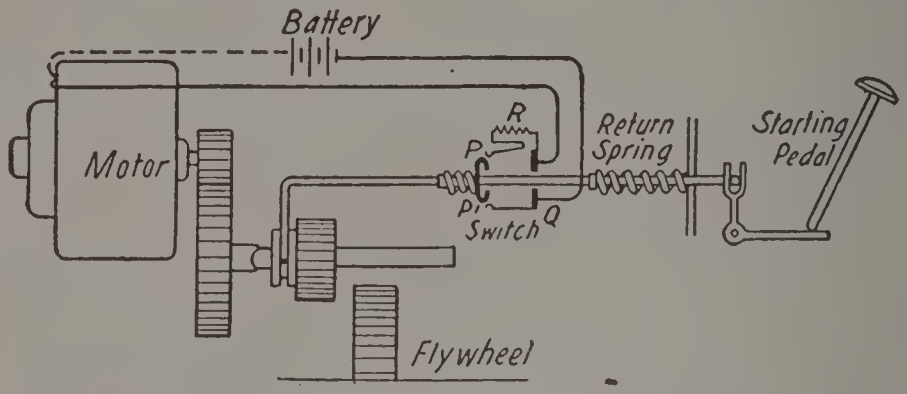


Figure 90.—Starting Switch with Resistance.

P, P'—Preliminary Contacts. R—Resistance.
Q—Main Contacts.

fully meshed or until the spring has been sufficiently compressed to mesh the gears instantly with the first application of power. Another method which will be found in a number of applications causes the pinion to revolve quite rapidly, but with very little power, so that the moving teeth will quickly find a meshing position with those on the flywheel rim. A system of this type, in which power is momentarily applied to the pinion and then withdrawn, is shown in Figure 90. The starting switch now has two pairs of contacts, *P* and P^1, and *Q*. Between the contacts *P* and *Q* is a resistance *R*. The pinion is normally held out of mesh with the flywheel teeth and in the

position shown. When the starting switch button is pressed down, the pinion is moved toward the flywheel, but before the teeth are in a meshing position the starting switch contacts P and P^1 are connected by the moving contact piece on the switch rod. Battery current then flows through the motor and to the switch contact through the resistance, which reduces the flow of current, and by way of the contact P, contact piece and contact P^1, to the wire and back into the battery. The armature shaft and pinion are then revolved at high speed with little power, and as the switch rod continues to move the pinion toward the flywheel, the contact piece in the switch leaves the contacts P and P^1, so that the pinion is left spinning but without any current passing through the motor. The revolving pinion slides into mesh with the flywheel teeth, and by the time the gears are fully meshed, the contact piece in the switch has come against the main contacts Q, thus closing the circuit between the battery and motor without the resistance, so that the full battery voltage is used for cranking. As in the last case considered, an overrunning clutch is carried in the starting motor housing or in one of the intermediate gears.

Another method somewhat similar to those just described is found in equipments that apply a small amount of power to the motor armature so that the pinion is kept revolving until the gears are in mesh. An example of this method is found in Delco motor-dynamos, whose armatures and fields each have two windings, one for generating and the other for starting. When the ignition switch is closed, the battery current is sent through the dynamo fields and armature windings so that the armature and the small starting pin-

ion is caused to revolve slowly and with very little power. As soon as the gears have been meshed, the full battery voltage is applied for cranking.

While most of the double-reduction gear applications described operate with an overrunning clutch between starting motor and crankshaft or flywheel, this unit is not absolutely necessary. A number of applications of Bijur systems have been made in which the sliding pinion is carried on the extension of the armature shaft and meshes with the flywheel teeth without the use of a clutch. In this case it is very essential that the starting switch be released as soon as the engine starts to fire, as otherwise the motor armature will be driven at dangerously high speeds.

STARTING SWITCHES

A majority of starting switches now in use may be divided into two classes, one of which (Figure 89) provides only a single pair of contacts that allow the full battery voltage to be impressed on the starting motor when the switch is closed, and the other one of which (Figure 90) uses two pairs of contacts in such a way that the battery and starting motor circuit is first completed through a resistance and then, with further movement of the switch, this resistance is cut out and the full battery voltage and current is used for cranking. The forms that these two types may take are many, and will vary with the make of equipment and with the model in almost all cases. Their construction is quite simple, both electrically and mechanically, and may be easily understood from a superficial examination. The contact points and the contact arms are built large and heavy so that

they are able to carry heavy amperage without undue resistance or heating. The starting switch terminals are oftentimes used for the attachment of lines used for the lighting and charging circuits, so that the wiring leading to and from the starting switch may apparently be complicated because of this use of its terminals for junction points.

A single pair of contacts will always be used with systems having a Bendix screw or inertia pinion for starting drive. The single contact switch may also be used with many of the systems having an overrunning clutch. A double contact switch is used when it is desired to start the pinion in motion before meshing takes place, and will be used when no overrunning clutch is provided.

Magnetic Switches.—Several Westinghouse systems have made use of a starting switch that is operated by an electromagnet, the electromagnet being energized when the driver presses a button conveniently located at some point within his reach. The connections for such a switch are shown in Figure 91, and the operation is as follows: When the pushbutton is pressed, current flows from the grounded side of the battery to the button, through the button and to the electromagnet winding in the starting switch. From the magnet in the switch the current passes to the dynamo, then back through a connection made in the switch housing, and to the other side of the battery. The pull of this electromagnet in the switch attracts the armature of the magnet, and this armature carries the contact piece for the main switch contacts. With the main contacts closed, the current flows through the switch and to the starting motor. In series with the starting motor circuit is a solenoid

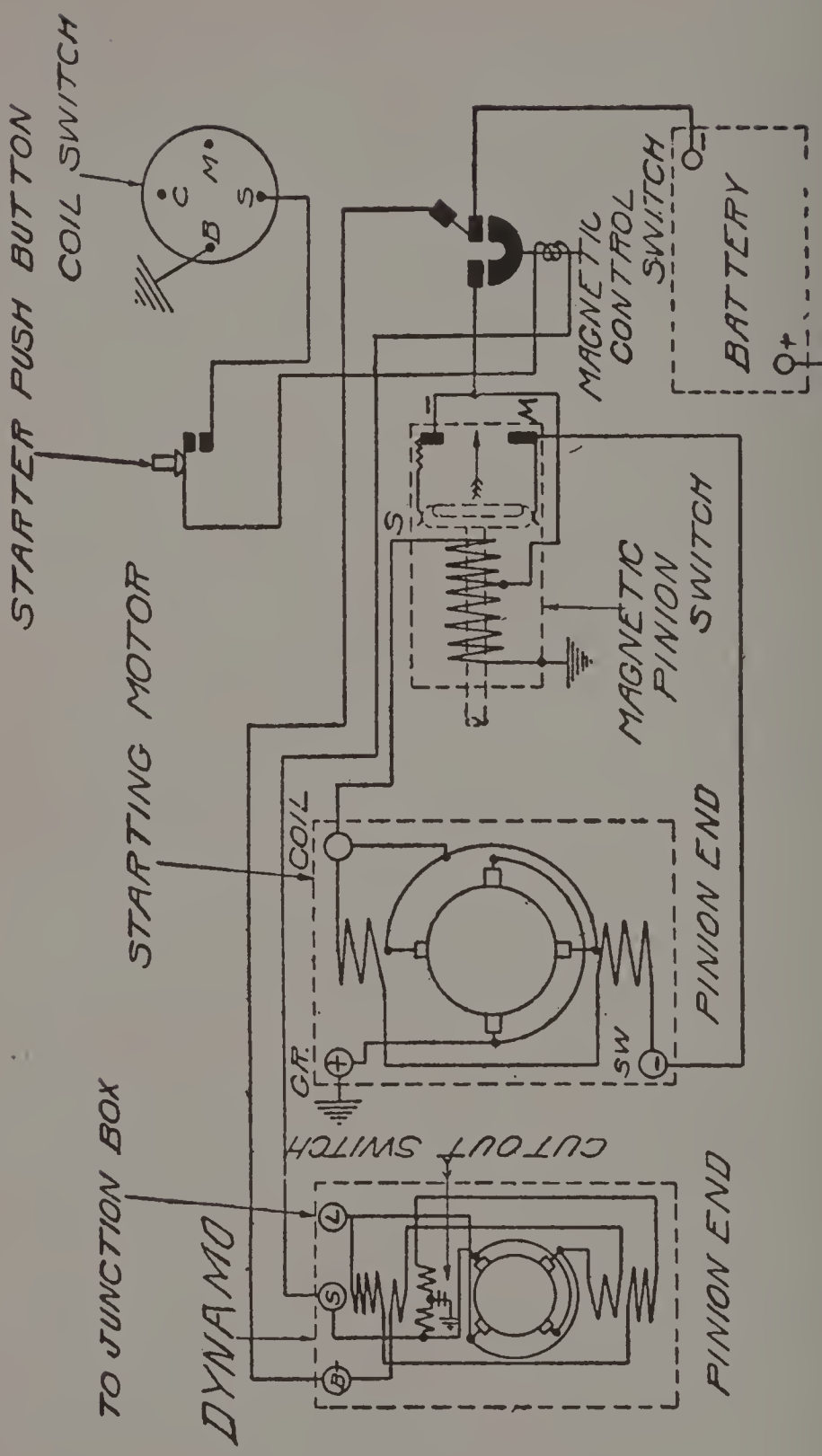


Figure 91.—Magnetic Starting Switch and Gear Shift (Westinghouse).

through whose windings passes the core attached to the gear meshing rod, and the gears are brought into mesh by the action of this solenoid. The starting button causes the switch magnet to become energized, and the flow thus allowed to pass through the switch energizes the solenoid so that the gears are meshed. As soon as the engine starts to run, it drives the dynamo, and the current from the dynamo that passes to the battery flows in a direction opposite to that allowed by closing the starting button with the dynamo idle. Because of this reversal of current, the electromagnet in the switch is demagnetized just as soon as the cut-out closes, and the starting switch contacts are immediately opened. No amount of pressing on the start button can cause the starting switch to close and the gears to mesh with the engine running for the reason that the current for this operation cannot pass to the electro magnets while the cut-out is closed.

Motor Brush Switches.—A movement of the starting motor brushes, either one or both of them, has been used with many of the Delco systems, and with some others, to take the place of a switch. By this method (Figure 92), the starting motor brush arm is pivoted so that the brush may be drawn away from the commutator surface or allowed to rest on it. With the engine idle the brush is held away from the commutator by linkage from the starting pedal connections. With the usual construction an extension on the starting brush-arm is used to complete the connection between the dynamo brushes and the battery circuits. When the ignition button is closed, or when the electromagnetic cut-out contacts are closed by mechanical connections from the starting pedal, the

battery current flows through the dynamo armature and fields and causes the armature and starting pinion to revolve so that gear meshing can take place. When the starting pedal and its connections have moved

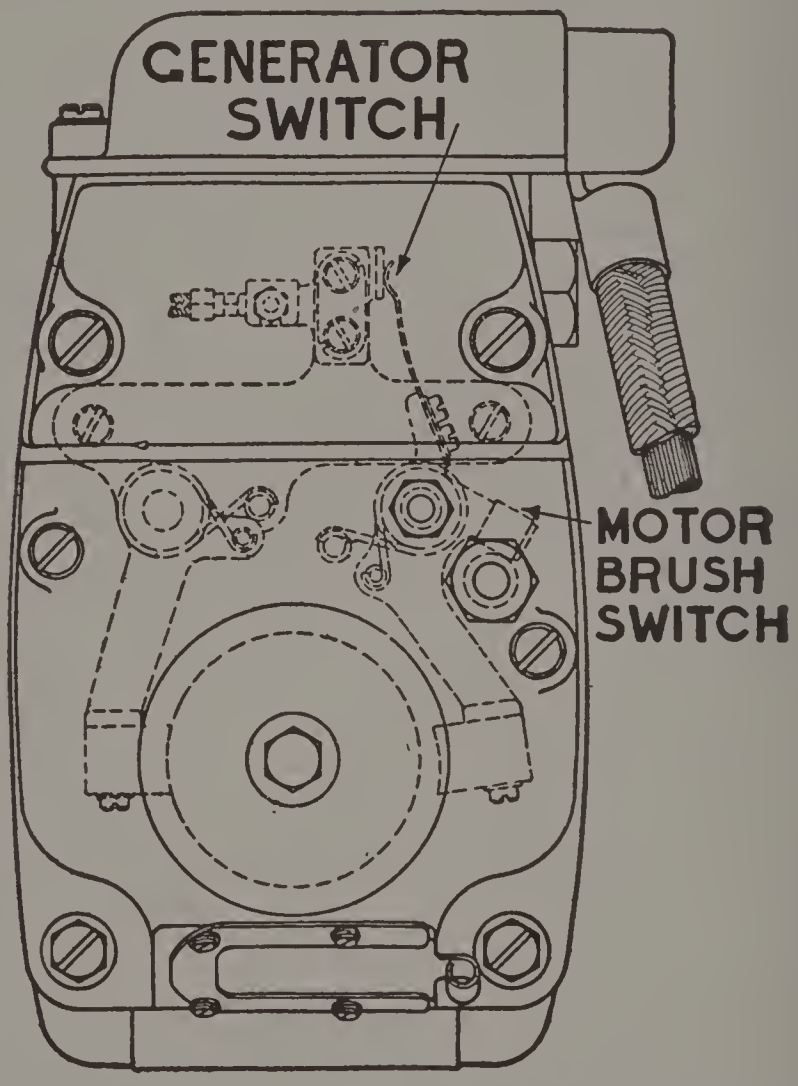


Figure 92.—Starting Switch Action with Movable Brush (Delco).

into such a position that the gears are in full mesh, the connections in the motor-dynamo housing allow the movable starting motor brush to drop onto its commutator, thus completing the battery circuit through the starting coils on the armature and through the series field windings. When the starting

brush drops onto its commutator, the movement of the brush-arm causes the connection from the dynamo brushes to the battery to be broken so that during the cranking operation no current can flow to or from the dynamo windings. As soon as the engine has started, the pedal is released and the gears pass out of mesh at the same time that lifting of the movable starting brush breaks the starting circuit while re-establishing the dynamo connection with the battery lines so that charging can take place.

Motor-Dynamo Switches.—Motor-dynamos may be divided into two classes, one of which will include those machines that complete the connection between battery and electric unit for starting and then allow this connection to remain closed while the motor-dynamo speed becomes high enough to cause battery charging. (See Figures 59 and 60.) The other class includes those machines that complete the connection for starting through one of the usual forms of starting switch and complete the charging connection through an electromagnetic cut-out. The latter system is always used with installations that use a high starting voltage and a comparatively low charging and lighting voltage, because it would be manifestly impracticable to allow a machine that generates a low voltage to remain connected to the battery with the battery sections so connected as to produce a high voltage, as used in starting.

The connections made by switches which establish a circuit that is maintained for both starting and charging have been described in Chapter V under "Cut-Outs." Practically any of the types making a single contact for starting may be used with dual voltage equipments.

Commutating Switches.—The type of switch used with motor-dynamos that use a starting voltage higher than the charging voltage is known as a commutating switch, because it changes the connections between the battery and the electric machine to allow for either of the functions to take place. With such switches in the idle or running position, the sections of the battery are connected in parallel or multiple, so that the voltage of the whole battery will be no greater than one section and will be correct for lighting and charging. With the switch in the starting position, the battery sections will be connected in series with each other, and the voltage of the whole battery will be equal to the voltage of one section multiplied by the number of sections used.

The connections made by the switch used with Splitdorf-Apelco systems, having twelve-volt starting and six-volt lighting and charging, are shown in Figure 93. The two positive terminals of the battery are connected to the switch terminals marked $+A$ and $+B$, while the negative terminals of the battery sections are connected to terminals $-A$ and $-B$-D. Eight contact points are carried inside of the switch, four of which are connected, two and two, in the running position, while the remaining four are likewise connected, two and two, during cranking. With the contact members in the running position, the flow of current is as follows: From the positive terminal of the motor-dynamo, as a dynamo, through the cut-out and to the starting switch terminal marked $+A$, by means of the wire *12*. From this terminal the current flows through one line directly to one of the positive terminals on the battery and also through the internal connections of the switch and through the contact

member to the switch terminal $+B$ and to the positive terminal of the other battery section. From the

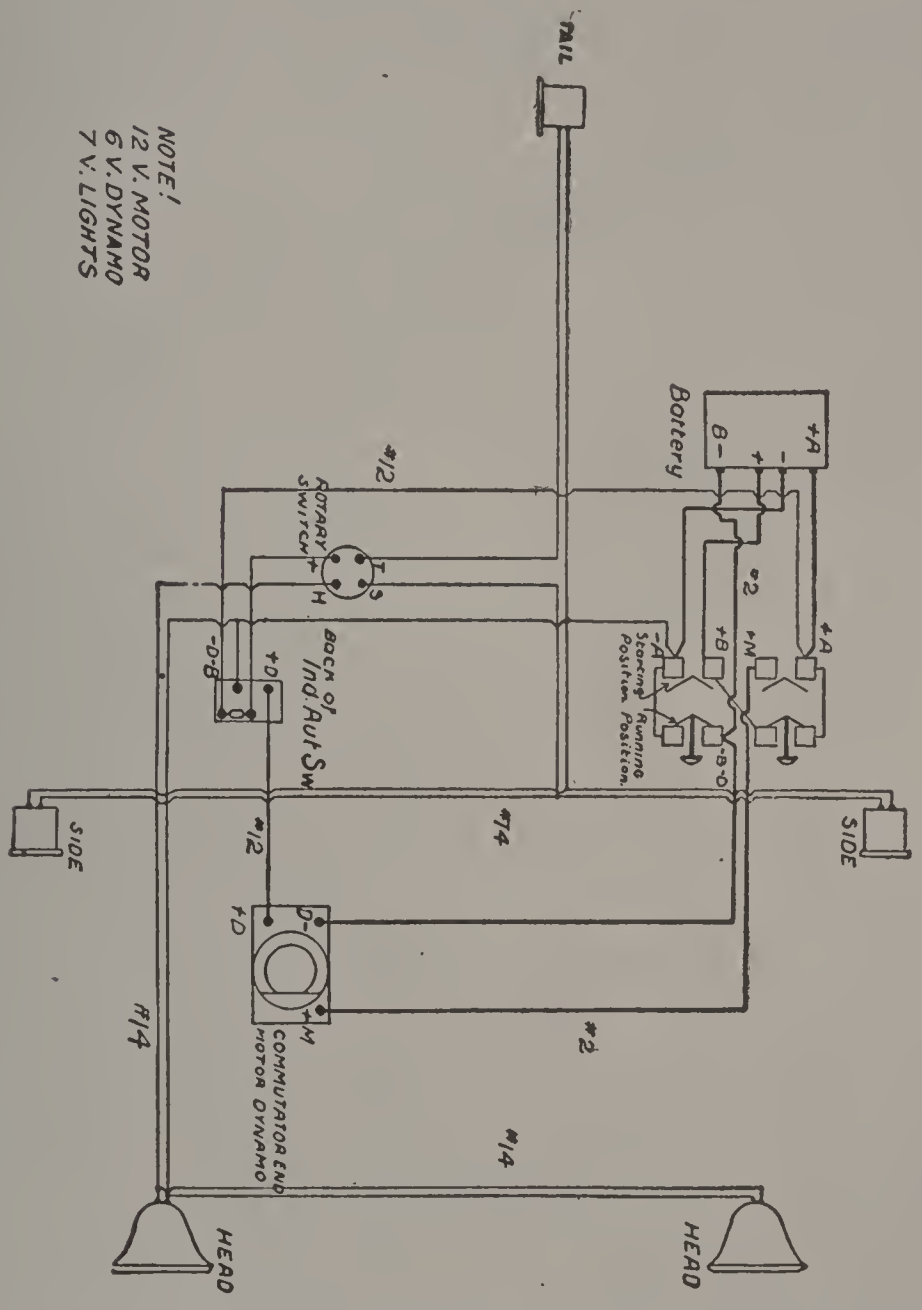


Figure 93.—Connections for Commutating Starting Switch (Splitdorf-Apelco).

—*B-D* switch terminal, which carries the line from one of the negative terminals of the battery, another line runs directly to the negative dynamo terminal of

the motor-dynamo, while the connection from the switch terminal —*A* and the other negative terminal of the battery comes through the internal connections of the switch and the other contact member to the switch terminal —*B-D*, where it joins the current from the other battery section in its path to the dynamo. It will thus be seen that both sections of the battery are connected with the dynamo, with both positives together on one side and both negatives on the other side of the starting switch.

With the switch contact members in the starting position, the flow of current is as follows: From one of the positive terminals on the battery to switch terminal +*A*, then through the switch contact piece to terminal +*M*, and to the starting motor terminal on the motor-dynamo. Passing through the starting motor fields and armature of the motor-dynamo, the current returns to switch terminal —*B-D*, and to one of the negative terminals on the battery through the other line attaching to this same switch terminal. Passing through this section of the battery, the current flows to switch terminal +*B*, through the switch contact member and to terminal —*A*, thence back to the negative terminal of the battery section from whose positive terminal the tracing of the flow commenced. It will thus be seen that the flow is through each section of the battery, first one and then the other, also through the starting motor, so that both sections of the battery and the starting motor are in one series circuit.

The connections made by the Simms-Huff commutating switch are shown in Figure 94. The sliding contacts move from right to left in the position illustrated, and are drawn in full lines for the running

and charging position and in dotted lines for the starting position. In the charging position one of the positive terminals of the battery connects with switch terminal *1*, and through the wire *A* to terminal *4*. The other positive terminal of the battery connects with switch terminal *5*, and through the sliding contact piece with terminal *4*. Both sides of the battery are thus joined at *4*, and from this terminal a line leads through the cut-out (not shown) to the posi-

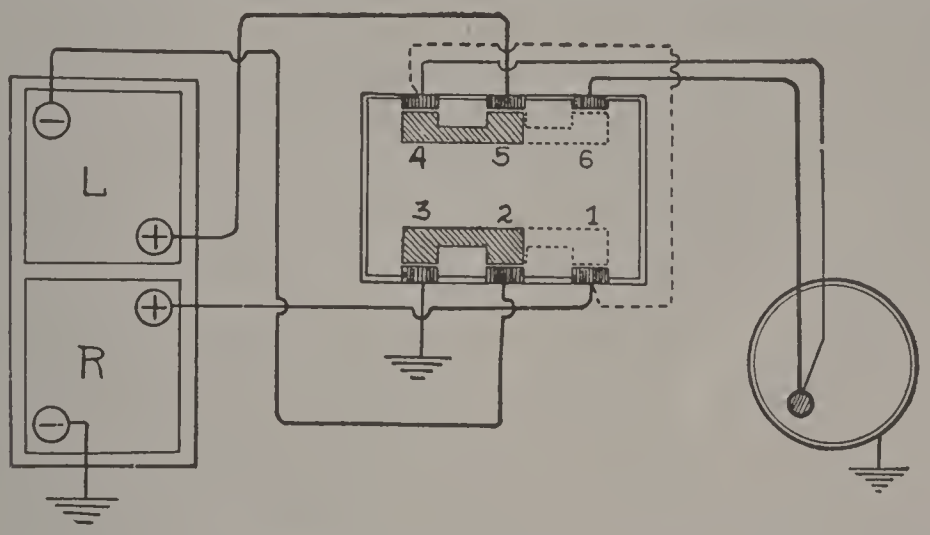


Figure 94.—Commutating Starting Switch with Sliding Contacts (Simms-Huff).

tive terminal on the motor-dynamo. The negative side of the motor-dynamo is grounded, and one of the negative terminals of the battery is also grounded directly. The other negative terminal of the battery is attached to switch terminal *2*, and by means of the sliding contact piece to terminal *3*, which is grounded. Both battery negatives are, therefore, connected together, and both positives are likewise connected. The positives are connected to the positive side of the dynamo and the negatives are connected with the negative side of the dynamo through the ground connections.

With the switch contacts in the starting positions, the current flow starts from the positive terminal of the battery section marked *R* and passes to the switch terminal *1*. Then through the contact piece in the switch to terminal *2*, and back to the negative side of battery section *L*. After flowing through section *L*, the current passes to switch terminal *5* from the positive side of the battery section, and through the contact piece in the switch to the starting motor terminal on the motor-dynamo. Passing through the motor, the current flows to ground and through the metal of the car returns to the grounded negative terminal of battery section *R*, having completed a series circuit through both battery sections and the motor-dynamo.

CHAPTER VII

INDICATING DEVICES AND TROUBLE LOCATION

Because of the fact that almost any trouble that may come to the electrical equipment will cause some change in current flow or pressure, the subject of indicating instruments is closely allied with that of trouble location. As mentioned in Chapter I, there are six divisions into which most all of these instruments may be divided, these divisions being the ammeter, the voltmeter, combined voltammeters, current indicators, moving targets, and pilot lamps.

Ammeters.—Ammeters may be built upon any one of a number of different principles, and they may be built cheaply or made very expensive. Regardless of the type or quality of the instrument, the flow of current which conforms to the definition of one ampere remains the same, and because of this fact the various constructions will not be treated at length. As a general rule, the construction of an ammeter and a voltmeter does not differ materially according to whether the instrument is to measure amperes or volts. In the case of the ammeter, the flow is allowed to continue without appreciable resistance, and it is this flow of current that is measured. With the voltmeter the flow is practically stopped because of the very high resistance of the instrument, and this stoppage allows the pressure that is acting in the circuit to be measured. Even in the case of the voltmeter (for all types in general use) there is some passage

of current, and the construction and principles of action are the same as for the ammeter, the sole difference being in the amount of flow allowed to pass through the instrument.

Ammeters are provided with a pointer or hand which moves from side to side with increase or decrease of flow through the circuit in which the instrument is placed. The pointer moves across a scale graduated in amperes or fractions and multiples of amperes and having a zero point at or near the center of the gradu-

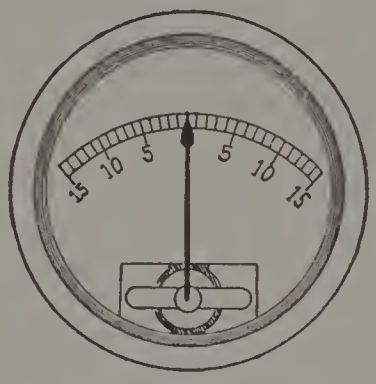


Figure 95.—Zero Center Ammeter.

ations. The pointer will move one way from this zero point with flow of current in one direction, for instance, into the battery, and will move in the opposite direction from the zero point when current flows in the opposite direction, as would be the case during battery discharge. This type of instrument is known as a "zero center" ammeter (Figure 95). If the meter was built in such a way that the hand stood at one side of the scale when at zero, it would only measure the flow of current in one direction, and would not be suitable for attachment on the car.

Ammeter scales may be marked "Charge" on one side and "Discharge" on the other side of zero, and when marked they should be so connected to the bat-

tery circuits that the hand will swing to "Discharge" when current is flowing out of the battery, such as would be the case with lamps turned on and the engine standing idle. The hand will then swing to "Charge" when current is flowing from the dynamo into the battery.

An ammeter should be placed on a car and so connected that it will measure all of the current flowing into the battery from the dynamo, and so that it will measure all current leaving the battery except that used for starting. An ammeter sufficiently great in capacity to measure the large flow during the cranking operation would have a scale too coarsely divided to measure the small currents used for charging and lighting. It is, therefore, necessary to find a wire on the car that carries all of the charging current and all of the lighting and other accessories' current, but none of the starting current. This may usually be done by following either one of the large battery cables until a smaller line branches from this cable. The ammeter may then be attached in this smaller line and just as close to the large cable as possible. Provided the wire selected carries all of the lighting and charging current and none of the starting current, the ammeter will then indicate the net charge and discharge other than for starting.

Should the charging wires and the lighting wires be connected to the large cables from the battery at different points along these heavy cables, it will not be possible to attach an ammeter to show both charge and discharge. This will also be the case with a great many motor-dynamo systems in which no line can be selected that carries both charging and lighting currents that does not also carry the starting am-

perage. It will often be found possible to attach an ammeter so that it will show charge into the battery, but no discharge for the lamps and other current-consuming devices. It will also be possible to attach an ammeter to one side of a separate dynamo so that the dynamo output will be indicated, this method, however, being of comparatively little value because it is the current entering the battery that is more essential than that furnished by the dynamo. In the absence of special directions for attaching an ammeter it will be necessary to follow the wiring as described or else to examine a wiring diagram of the car or system in question until a line is found that does not carry the starting current but that does carry the currents whose value it is desired to measure.

With an ammeter connected, some lamps should be turned on and the direction in which the needle moves noted. If the scale is marked "Charge" and "Discharge," the needle should move toward "Discharge," and if it does not do so, the wires should be removed from the ammeter terminals and interchanged with each other. In case the face of the meter is not marked, the connections should be made in such a way that the needle will swing to the right of zero for charge and to the left for discharge.

Voltmeters.—A voltmeter may be attached between any two points or any two wires whose difference in pressure or voltage it is desired to measure. While an ammeter should always be placed in series with the circuit whose flow it is to measure, the voltmeter is very seldom placed in series for the simple reason that its resistance is so high that practically no current flow could take place with the instrument so

connected. In connecting an ammeter, the circuit is broken at some point and one side of the meter connected to one end of the circuit, while the other side of the meter is attached to the other end of the circuit. No such procedure is necessary with a voltmeter, it being only necessary to place the wires from the voltmeter on the points whose voltage is to be measured, and the needle of the instrument then shows the voltage difference existing at that time.

When voltmeters are mounted as part of the equipment of a car, they are attached to the positive and

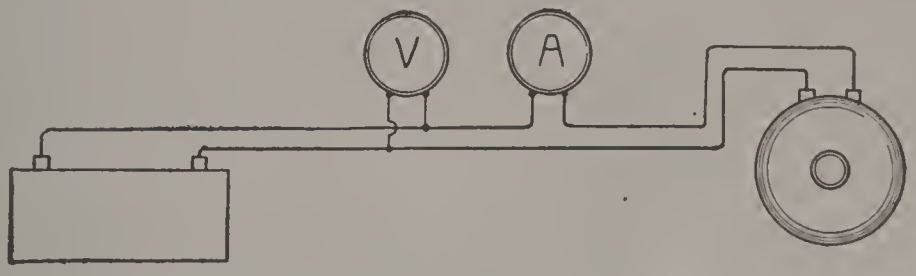


Figure 96.—Voltmeter and Ammeter Connections.
A—Ammeter. B—Voltmeter.

negative side of the circuit between battery and dynamo, and usually on the dynamo side of the cut-out (Figure 96). A voltmeter draws such a very small flow of current that the loss from this use may be neglected while the engine is running. However, it would not be advisable to connect a voltmeter directly to the terminals of a battery and allow it to remain there, because even such a slight flow of current continued without any interruption would eventually discharge the battery wholly or partially. To attach a voltmeter correctly, the car's wiring should be examined and the line from the dynamo to the cut-out found. One side of the voltmeter should then be attached to this line, either at the dynamo or cut-out or any other convenient point. The other side of the

voltmeter may then be attached to any other wire or terminal between battery and dynamo, provided that this second point of connection is of opposite polarity from the first. The meter will then indicate the charging voltage at all times while the engine is running fast enough to close the cut-out.

Voltmeters are sometimes attached directly to the battery so that they indicate the battery voltage or the voltage at the battery terminals at all times. Such a connection should not be made unless the meter is known to be of a type designed for such use, and should then be used in accordance with instructions given by the makers of the car or of the electrical equipment.

Voltammeters.—Because of the similarity between the voltmeter and the ammeter, it is quite possible to use a single instrument for both purposes. The voltammeter consists of a single movement which is fitted with suitable terminals and resistances to allow its use in either capacity. Voltammeters are usually provided with one terminal for use in voltage measurements, with one terminal for use in measuring amperage, and with one terminal for use with either one of the two first mentioned, regardless of whether volts or amperes are being measured. A voltammeter may be provided with a switch which is turned to take voltage readings, or may simply require that the connection be made on the voltmeter terminal. While such combinations are in common use as portable testing instruments, they are seldom found attached to the automobile as a permanent part of the electrical equipment.

Indicators.—These instruments have faces or dials showing three conditions—"Charge," "Off," and

"Discharge"—the "Off" position corresponding to zero on the ammeter. They are constructed on the principles employed in the ammeter, but do not measure the exact amperage. They may be so constructed that attachment in the main battery circuit is possible and so that all charging current and all discharge, including that for starting, passes through them. With the engine running fast enough to cause charging, and with the lamps and other current-consuming devices out of use, an indicator should show "Charge." With any current being drawn from the

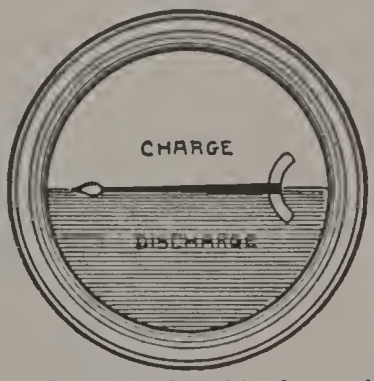


Figure 97.—"Charge-Off-Discharge" Indicator.

battery the instrument should show "Discharge." (See Figure 97.)

Targets.—Because of the fact that some part of the electromagnetic cut-out must move when the connection between dynamo and battery is completed, it is possible to use some visible marker or target attached to the cut-out as a current indicating device. It should be understood that because the cut-out is closed it does not necessarily mean that the battery is being charged. The lamps turned on at that time may be consuming all of the current generated, or the cut-out itself may be defective and not completing the circuit to the battery, although apparently doing so.

Pilot Lamps.—Dash lamps connected in such a way that they light up when the cut-out closes are used with some installations. The same caution applies in a certain measure as given for the target, that is, that this type of indicator does not necessarily prove that the battery is being charged. A pilot lamp connected between dynamo and battery is a fairly reliable indication, however, and because of the proportion of charging current that passes through it, the lamp should never be allowed to remain out of its socket or burned out.

It should be borne in mind that all types of current-measuring and indicating devices are subject to troubles that render their indications of little or no value. Ammeters and voltmeters should be watched to make sure that they indicate zero when the engine is idle and all lamps out. If there is an error either way, this error should be allowed for in making readings with the instrument. It may happen, and often does happen, that the magnet used in these instruments becomes damaged or too weak to perform its work, and in this case the meter will become very sluggish and its hand will tend to stay in whatever position it comes to rest until the current flow is high in value. While the higher-priced instruments have provision for resetting the hand or dial at zero, the low-priced voltmeters and ammeters are valueless when damaged, and it is economy to replace them with new ones.

STARTING AND LIGHTING TROUBLES

Faulty operation of the various units may appear in one of two forms, either electrical trouble or mechanical trouble. Mechanical troubles include

those caused by loose, broken and worn parts, by incorrect assembling and lack of proper care and upkeep, such as lubrication and cleaning. Electrical troubles include the faults that prevent the current from traveling in its proper paths and from doing the work that is expected of it. Almost all electrical troubles may be placed under one of four headings, namely: (1) open circuits, (2) circuits having abnormally high resistance, (3) short circuits, and (4)

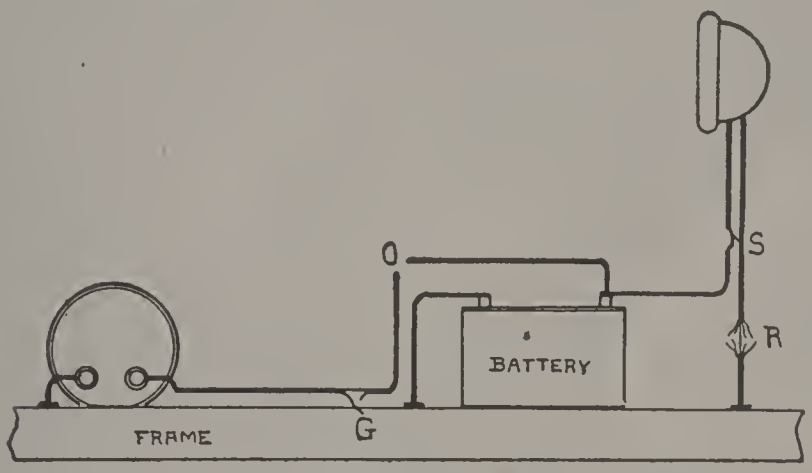


Figure 98.—Troubles in Wiring System.

G—Accidental Ground.
O—Open Circuit.
R—High Resistance.
S—Short Circuit.

the modification of short circuit called a "ground." (See Figure 98.)

An open circuit occurs whenever a wire breaks or becomes detached from one of its terminal connections so that the current can no longer flow. An open circuit may also be caused by an improperly made or dirty connection in which the current-carrying surfaces do not make proper contact with each other. Any fault that prevents the current from flowing because of the lack of a complete path or circuit away from and back to the battery is said to result in an open circuit, or simply an "open."

High resistance may result from poorly made or dirty contacts in which the current-carrying surfaces are in partial contact. The area of the conductors is so reduced in size that all but a small amount of current is prevented from passing the point of high resistance. Wires that are partially broken through and wires that are too small for the work they must do will cause an abnormally high resistance. Dirty, pitted or corroded contacts in the dynamo, cut-out or regulating parts will cause high resistance, and, in fact, any fault that results in a partial stoppage of current flow through a circuit that should be complete and of low resistance will bring this trouble about.

A short circuit is established whenever an accidental current-carrying path occurs in a circuit at a point that allows a flow from the battery when there should be no flow, or that allows the current to leave the battery and return to it without passing through the lamps or other devices that are designed for current consumption. The success of any electrical installation depends on the flow of current being kept within the conductors designed to carry it, and should the insulation fail or should exposed parts come into contact in such a way that an improper flow is allowed, the result will be a drain on the battery, failure of the dynamo to generate, failure of the starting motor to act, or a failure of almost any of the electrical units, depending on the point at which the short-circuit occurs.

A ground is a form of short-circuit that is established through the metal work of the car. With the one-wire system, or the grounded return system, an accidental ground will occur whenever a current-

carrying conductor comes into electrical contact with a part of the metal of the car. With a two-wire, or insulated return system, it is necessary that both sides of the circuit come into electrical contact with the metal of the car. This fault is rarely met with in the two-wire system because of the fact that the metal work of the car does not ordinarily act as a conductor for one side of the circuit.

Indicating Instrument Faults.—Because of the fact that ammeters, voltmeters, etc., are primarily designed to tell what is happening and to aid in locating trouble, it should not be assumed that these units themselves are free from error. Outside of trouble caused by open, short or grounded circuits and circuits of high resistance in the wiring and terminal connections of these instruments, they may develop trouble within their mechanism. Should an ammeter be subjected to a current much greater than it is designed to carry, such as would be the case were an ordinary instrument connected in the starting circuit, the current-carrying coils would be burned out and the meter would have to be rebuilt before further use could be made of it. An ammeter or voltmeter of the permanent magnet type, such as is ordinarily employed, will lose its accuracy if exposed to heat, sudden jars or a strong magnetic field. The first and most apparent effect of such a happening will be a sluggish action of the indicating hand. The hand will move slowly from place to place on the dial, and will not return to zero until jarred, if at all. It is quite frequently found that a meter hand does not return to the zero point when current flow or pressure is removed, yet the action may be satisfactory in all other ways. To overcome this difficulty, to which all

meters are more or less subject, high-grade instruments are provided with a "zero center" adjustment by which the tension of the springs controlling the movement may be changed or by which the dial itself may be moved until the position is again correct.

When an ammeter or voltmeter is in proper working order, the hand should remain at zero with one or both of the wires removed from its terminals. Should there be an error at this time, the number of amperes or volts should be noted and allowed for in future readings. The hand should move quickly from point to point and should come to rest within a reasonable time.

Should an indicating target such as is attached to an electromagnetic cut-out fail to indicate charge with the engine running at a fair rate of speed, trouble in the cut-out is indicated, or else a failure in the dynamo or other parts of the charging system that prevents the cut-out from closing. Failure of a pilot lamp to light indicates that the lamp bulb is broken or burned out or else that one of the cut-out troubles mentioned above is present.

LIGHTING SYSTEM TROUBLES

The lighting system of the car consists of the lamps, together with the necessary wiring, switches, fuses, circuit breakers and junction connections. Lighting trouble that is not a result of lack of charge or voltage at the battery will be found in one or more of the above mentioned units.

In case of failure to light, the bulbs themselves should be examined to make sure that they are not broken and that the filaments are not burned out. Should the lamp have been fitted with bulbs designed

for a voltage lower than that used on the car, the filaments will be burned out, while bulbs designed for a higher voltage than that used will not light at all. The average life of a good tungsten filament bulb should be from 100 to 300 hours, but low-efficiency or cheap bulbs may become dim or may burn out in much less time.

It is quite possible for dirt, loose wire strands or faulty construction to cause an accidental short-circuit in the bulb base or in the socket into which the base fits. Such a fault will probably result in allowing such a heavy flow of current at the defective point that heating will result, and at the same time all the other lamps on that circuit or line will burn dimly or not at all. It may be found that the small contact points on the bottom of the bulb base do not make contact with the plungers or springs in the socket. The springs may be bent up slightly or the contact points may be extended by the addition of a drop of solder to each. If the socket contains spring plungers, they should be pressed down and examined for binding or dirt that will cause sticking when the bulb base is pressed home. If the plungers can be pressed down and then remain down, it indicates that the springs have become broken or are binding, and a new socket is the most satisfactory remedy. The interior of the bulb sockets should be kept free from dirt and foreign matter of all kinds because the result may be either a short-circuit or an open circuit for that particular lamp. It is customary to provide the lamps with connectors into which the wires fasten and which complete the circuit by means of plungers or pins that fit into holes in a second part of the connector. The same remarks respecting dirt and

poor connections apply to these outside connectors as to the bulb sockets. Should the lamps flicker and occasionally go out altogether, the wiring at the sockets and at the connectors should be examined for loose strands. In case a part of the copper is found exposed, it should be wrapped with insulating tape to prevent a repetition of the trouble caused by the movement and jarring of the car while in motion.

Should trouble manifest itself in one or more lamp groups and no faults be found with the lamps or bulbs, the wiring for the affected portion of the equipment should be carefully examined to locate possible short, open or grounded circuits. The insulation should be perfect along the entire length of each wire, and any worn places should be well wrapped with tape. The points at which the wires turn around corners, and the points of fastening by means of cleats on the metal work, should be given a careful inspection, and the conductors should be moved wherever possible while the lamp switches are turned on to test for broken wires underneath the insulation. In case the candlepower of the lamps has been increased, or in case additional lamps or other accessories have been added to any of the circuits, it is quite possible that the wire originally used may be too small for the added load. Lamp circuits should be made with wire not smaller than No. 14 gauge, and 12 gauge will be safer in case of any added load. Wires of opposite polarity should not be run so close together that they touch unless they are bound together with tape or fasteners, because of the chafing that will result. In case it is necessary to run lines through places where they will become wet or oily, the wiring should be enclosed in metal conduits or by

circular loom, and the openings through which the wires enter and leave the protecting coverings should be tightly taped.

A large number of cars are equipped with bus-bars, junction blocks or boxes and distribution panels at the terminal posts of which several lines meet and are connected together (Figure 99). These points of connection may develop short circuits between the several cables of different circuits, or may contain accidental grounds on the metal work of the car. Loose strands of wire should be carefully guarded

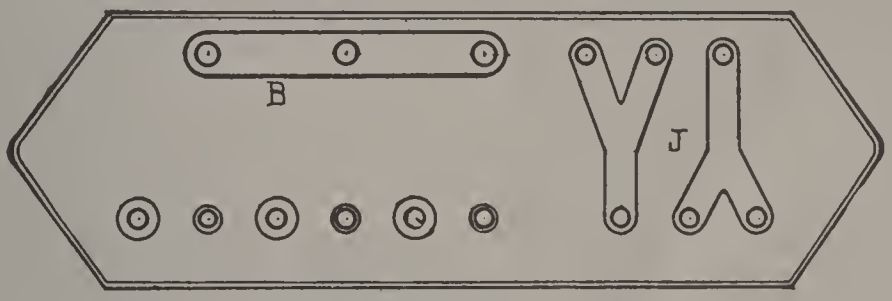


Figure 99.—Distribution Panel.
B—Bus-Bar. J—Junctions.

against, and all such wire ends should be fitted with metallic terminal pieces that hold all the wire strands by means of the solder used in making the attachment. It is often found that dirt, oil or moisture enters these connection boxes through the wire openings, and in case the junctions are located at points exposed to such trouble, it will be well to tape each line where it enters the enclosed portion of the junction.

In the case of a car equipped with fuses in the lighting or charging lines, these units should be examined to make sure that the circuit can be completed from end to end. The fuses are designed to protect the equipment against short circuits and overloads, and

should a fuse be found burned out, the line leading away from it should be examined for the short circuit that is almost sure to be found. It will do no good to replace a fuse in a lighting circuit until the cause of its burning out is found and remedied, because a new fuse will only suffer in the same way as the old one as soon as the faulty conditions reappear. Fuses should never be replaced with others of a higher capacity than those originally furnished with the car, because the protection to the circuits and other units will no longer be present. The final result of such replacement will probably be damage many times more serious and more costly than the new fuse of the proper size would have been. Such advice applies even in stronger measure to replacement of fuses with lengths of copper wire. This is the poorest kind of economy and should never be practiced. It will oftentimes be found that a failure to complete a circuit through a fuse is due to poor contact of the fuse with its holding clips or due to poor contact of the clips and terminals with the wire ends that are attached at these points. A minute piece of foreign matter between the fuse and the clip will prevent a flow of current, and before deciding that the fuse is burned out, it should be turned around in the clips once or twice to remove any such particles. The clip ends should be pressed together until they hold the fuse firmly, and the screws that hold the wire terminals should be turned down tight.

The contact points of circuit breakers should give no trouble because they are so seldom called upon to do any work. In case of high resistance or an open circuit in lines protected by these devices it can do no harm to examine them and to clean the contacts

by drawing strips of very fine emery cloth between them while held closed. In case a circuit breaker opens, it indicates an overload on that line, and this overload, whether caused by short circuit, ground or improper connections, should be located before the breaker is closed. Some types of circuit breakers will open and close rapidly with a buzzing noise as long as the trouble is present, and the spring tension or adjustment should never be changed to overcome an accidental leakage of current.

Should the lamps flicker or go out entirely, it is possible that the trouble will be found in the lighting switches. These switches are simple in construction, and their action may be understood in each case by an examination. The contacts should be examined to make sure that they close their respective circuits and to make sure that the leaves are not bent or binding and that the surfaces are clean and bright. The moving parts of the switch may have become loose so that they make only an intermittent connection while the car is in motion, and all of the internal parts should be moved by hand to determine whether this trouble is present. The terminal studs and nuts should be watched for looseness or breakage, either external or internal, and in case of any doubt as to the proper connections being made, a wiring diagram for the car being handled should be consulted.

CHARGING SYSTEM TROUBLES

Any failure of the dynamo, cut-out, regulating device or charging wiring will result in the specific gravity of the battery electrolyte becoming abnormally low, and in the voltage of the battery falling below two for each cell. As far as the wiring is concerned,

the same advice as that given for the lighting circuits may be applied to this case. Other troubles may come from faulty conditions of the dynamo brushes, commutator, armature or fields, or from faults in the cut-out and regulator.

In case a test at the dynamo with an ammeter shows no flow of current, or if a voltmeter test shows no voltage being generated, it may be assumed that parts inside of the dynamo housing are at fault. While either the cut-out or regulator or both of these units may be carried inside of or on the dynamo housing, they are not properly a part of the dynamo, and will be given separate consideration.

With the brushes exposed, their holders should be examined to see that the pivoted arms are free to swing back and forth, and that sliding brushes do not bind or wedge in any position. Such binding of the brush itself may be remedied by carefully dressing the sides with a fine file. Attached to each brush or to the brush holder is a short length of flexible wire called the brush pigtail. These small wires must not be broken and their connections must be clean and tight at each end.

Either the brush itself or else the brush holder is held by a coiled or flat spring so that the brush bears on the commutator surface with a tension just sufficient to cause the brush end to make good contact at all armature speeds. These brush springs should not be bent, loose, broken or binding, and should have sufficient tension to cause a good firm connection to be maintained, but should not be set up so tight that there is danger of the brush cutting into the commutator surface.

In all types of dynamos the brushes or their holders

are insulated from the remainder of the dynamo by means of bushings, washers and sleeves. These insulating parts must not be broken or cracked, and if covered with oil or carbon dust should be thoroughly cleaned. In the case of grounded return systems, the ground connection is made through the pig-tail, but the brush itself is insulated.

The end of the brush must exactly fit the curve of the commutator in those machines that provide brush contact on the curved outer part of the commutator. In case the contact surface of the commutator is formed from the flat side of the ring, the surface of the brush must then be perfectly flat and bear evenly at all points on the segments that pass under it during armature rotation. The brush end may be fitted to the commutator by drawing strips of thin fine-grain sandpaper between brush and commutator with the sand side toward the brush, this procedure having been described in the chapter on dynamos and shown in Figure 21.

The brushes should be replaced with new ones when worn down nearly to the holder or spring, and in making such a replacement the safest method is to secure the new brushes from the makers of the car or the makers of the electrical equipment. As a general rule it may be said that none but carbon or carbon composition brushes should be used, because of the fact that brushes made from copper or copper alloys tend to cut into the commutator surface and cause serious damage and rapid wearing. Even with carbon brushes in use, care must be exercised to see that the material is very fine and of smooth grain. Brushes that are light gray in color and that show a granular or rough surface are not safe to use.

Should the brushes be found in good condition, the commutator should be examined next. Its surface should be very smooth and should preferably have a glazed appearance and a dark brown color. In case the surface of the segments is found to be dirty, scratched, rough or pitted it may be dressed with fine sandpaper by following the method described in the chapter on dynamos. Excessive sparking will cause burning and pitting of the commutator surface, and this sparking will usually be found to result from the use of brushes of improper material or from the fact that the brushes do not make good contact with the commutator.

The segments forming the commutator should be examined to see that none of them are projecting above the surrounding surfaces and that all are up even with the curve of the commutator. These troubles may be corrected by turning the commutator in a lathe, but if the condition is the result of loose segments or fastenings, the armature should be sent to its makers for repairs. The small wires that connect the segments with the armature coils should be watched to see that they are unbroken and well insulated. Worn or broken insulation may be replaced by taping and then shellacing over the surface of the tape. If the connecting wires are broken they should be fastened in place with hard solder or silver solder.

The insulation between the segments should be below the surface of the commutator, and if found even with or above the surface of the surrounding segments, it should be dressed with some cutting tool such as described in the method given in Chapter II.

Armature and Field Testing.—In order to handle this class of work it will be well to secure a circuit

tester of some form which will indicate by a flow of current when a circuit is complete through a certain path and when it is incomplete. A very satisfactory tester may be made by cutting one side or one wire of an ordinary drop-cord such as is used for shop and garage lighting. See Figure 100. Cutting one wire in this way will cause the lamp to go out, even though the switch be turned on, but as soon as the two ends of the severed wire are brought together, the circuit will be completed and the lamp will indi-

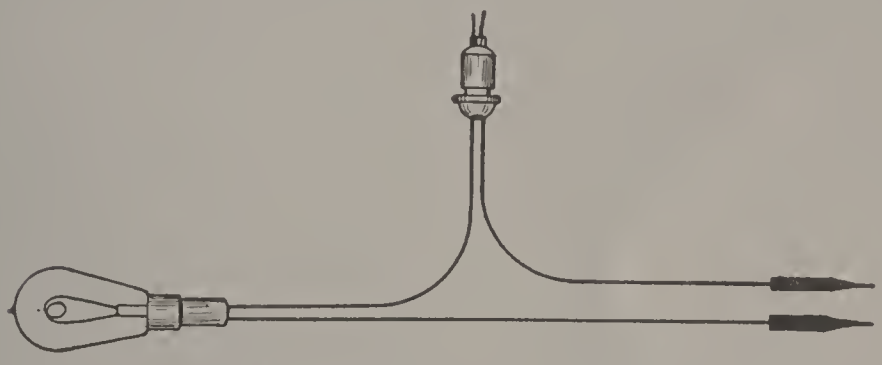


Figure 100.—Circuit Tester.

cate this fact by lighting. These two free ends of one side of the circuit may be used as a tester by touching them to any two points between which it is desired to make a test. For example, with the wire ends touched to the two ends of a conductor that is completing its circuit, the lamp will light because the circuit is now made through the conductor being tested. If the conducting path is not complete, the lamp will indicate this fact by remaining dark. In case it is desired to know whether or not a certain wire is grounded, one of the test wires may be touched to the metal of the car and the other test wire to the wire being tested. Should the lamp light, it indicates that the wire being tested is in electrical con-

nection with the metal of the car and is therefore grounded.

The troubles most commonly found with armatures are burned out or broken windings and windings grounded to the core or armature shaft. With one end of the test wire touching any point on the surface of the commutator, the lamp should light when the other test wire is touched to any other point on the commutator. Should the lamp remain out with the connection made at any point, it indicates that the winding connected to the segment being touched

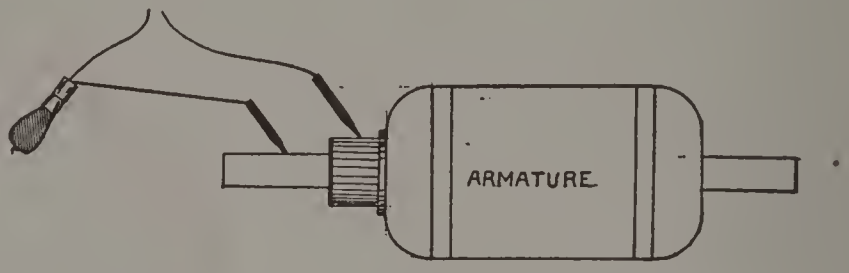


Figure 101.—Test for Accidental Ground.

is broken or that the segment of the commutator is disconnected from the armature windings. With one of the test wires attached to the metal of the armature shaft or armature coil the lamp should not light when the other end of the tester is touched to the commutator at any point on its surface. See Figure 101. Should the lamp light, it indicates that either the armature windings or the commutator segments are grounded. To remedy either of these conditions requires special equipment and experience and the work should be done by a shop able to handle it properly.

In order to test the field windings for possible troubles it will be necessary to reach the terminals or connections that carry the leads for these windings.

In the case of straight shunt wound dynamos having an external regulator, one end of the field winding will attach to one of the dynamo terminals, while the other end of the winding will lead either to another dynamo terminal, to a ground connection or directly to one of the main brushes. In third-brush dynamos one end of the field winding attaches to the regulating brush and the other end to one of the main brushes or to a second field brush. In either of the above cases, lifting one or more of the brushes away from the surface of the commutator will usually serve to

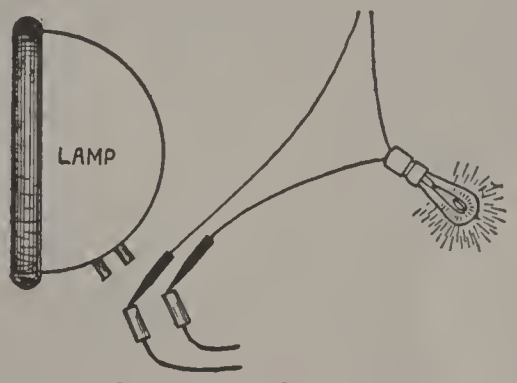


Figure 102.—Test for Open Circuit.

isolate at least one end of the field coils. The connections for compound wound dynamos, for dynamos with bucking coils or reversed series field windings and for motor-dynamos will vary according to the construction of the machine, and can best be found by examination and test or by consulting a wiring diagram that shows the internal connections.

Troubles that occur in the fields may take the form of burned out or broken windings or connections, of disconnected terminal fastenings, or of ground connections made with the core or dynamo frame. It should be possible to secure a connection from one end of the field windings through to the other end with the drop-cord circuit tester and the lamp

should light. Failure to secure such a connection indicates a broken or disconnected field circuit. With one of the test wires attached to the metal of the dynamo, the lamp should not light when the other end of the test wire is touched to either end of the field coil while the coil is disconnected from all other circuits and from the brushes and commutator. It should be noted that no circuit test, either to find whether a circuit is complete or grounded, is of any value unless the lines to be tested can be separated from all other connections during the test. Should any outside wiring be left connected, the circuit may be completed through another path than the one being tested and erroneous conclusions will be drawn in many cases.

The permanent field magnets used on some dynamos are subject to certain peculiar faults that will not occur with wound fields. These magnets will gradually become weaker and weaker with long continued use until they must be removed and remagnetized just as would the magnets of a magneto used for ignition. Permanent magnets must not be hammered or jarred violently, and at all times, while removed from the dynamo, the opposite poles should be joined with a small bar of iron or steel so that the path of the magnetic lines of force may be completed through this so-called "keeper." Should all of the magnets composing the set used on a dynamo be put on the machine with their poles placed in positions opposite to that originally occupied, the polarity of the machine will be reversed and serious damage to the battery will result if they are not changed immediately. Should part of the magnets be replaced in the correct position, but the remainder be reversed in position,

the several members will oppose each other in action and the dynamo output will be greatly reduced if not prevented altogether. It is not good practice to mount permanent magnet machines on bases made from iron or steel because the lines of force from the magnet ends will pass to a great extent through the metal of the base rather than through the core of the armature, and the dynamo output will be reduced in proportion to the loss taking place.

Cut-out Care.—Manual or hand-operated cut-outs require the same care and attention as called for by any other type of switch. Electromagnetic cut-outs

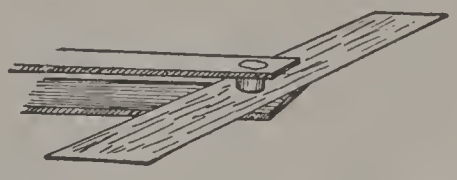


Figure 103.—Cleaning Contacts.

are of more complicated construction and are subject to a different class of faults.

The contact points of an electromagnetic cut-out should be kept clean and bright and should meet evenly and over their entire surface when the cut-out is closed. Should plain surface contacts be found dirty or pitted, they may be cleaned by drawing strips of thin emery cloth between them while holding them lightly together. See Figure 103. This method of using the emery cloth will also restore the surfaces to such a form that they make full contact in case they have become out of line for any reason.

When the engine runs at a charging speed, the cut-out contacts should be closed by the action of the magnet, provided the dynamo is giving the necessary voltage. Failure of the cut-out to close when the

dynamo is in good condition will usually be caused by loose or dirty connections of the wires on the cut-out terminals or possibly from a broken or burned out shunt winding in the cut-out magnet. If the cut-out closes, but does not complete the circuit for charging, the contacts should be examined and the terminal connections of the wires should be made clean and tight.

Regulation Trouble.—The characteristics and construction of the various systems of output regulation will be found described under their several headings in Chapter V. Their care will be described here in the same order and under the same names as used in the former description.

The reversed series field winding is not subject to any troubles that are peculiar to its regulating functions provided it has been properly designed and installed when the dynamo was built. This field winding is, however, subject to the same troubles that may be encountered with any shunt or series field and methods of locating such troubles have already been given.

The third-brush system adds nothing to the dynamo for regulating purposes except one or two additional brushes. These brushes require the same careful fitting that would be called for with any other current-carrying brushes and the field winding itself does not differ in any important particular from other shunt windings and may therefore be handled in the same way. The same remarks apply to those dynamos having compound field windings, inasmuch as in this case the entire regulating system is found in the series winding on the field cores.

The iron wire ballast coil of the Rushmore system

of control must be securely held in place by its clips, just as would be the case for a fuse similarly carried. See Figure 104. The output is affected by the size of wire used and information necessary in making any changes called for has been given in Chapter V. The coil should be tested in case of trouble to make sure that the iron wire has not become disconnected and has not been burned out or broken. These troubles will cause the bucking coil to act at all times with a resulting drop in dynamo output.

Any form of magnetically controlled field resistance operating on the vibrating principle requires

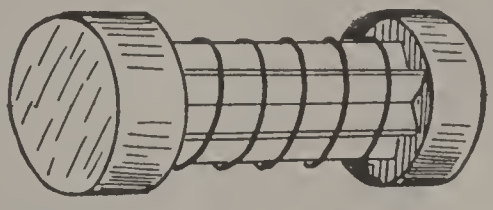


Figure 104.—Ballast Coil for Rushmore Iron Wire Regulation.

that the regulator contacts and terminal connections be given the same care as outlined for the electromagnetic cut-out. The contacts, when dirty, may be dressed by using very fine emery cloth drawn between them, and in this connection it should be noted that improper wiring of the controller may result in sending the charging current through the regulator contacts, which will result in rapid pitting and burning of the surfaces.

The systems that make use of carbon discs for field resistance require that the carbon pieces be cleaned occasionally by removing them from their holders and rubbing lightly on fairly rough paper. The end plates of the carbon piles should be cleaned with fine sandpaper.

The rheostats found with the Adlake and Vesta systems of control require cleaning of the contact segments at certain intervals. This cleaning may be accomplished by first wiping the surfaces with a cloth moistened in gasoline and then, should pitting appear, fine sandpaper may be used to remove the marks. The brushes should make good contact with the segments and their surfaces should be kept clean and smooth. The spring that holds the brush in place should have sufficient tension to ensure a good

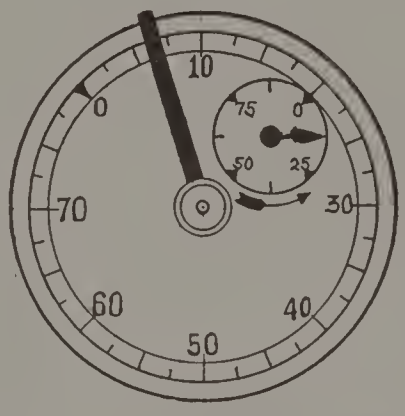


Figure 105.—Dial of Ampere-Hour Meter (Delco).

current-carrying contact at all times, but should not bind the contact arm. The plunger of the Adlake controller should move freely within its socket and may be cleaned with a gasoline moistened cloth in case of sluggish action.

All forms of friction clutch governors operated by centrifugally controlled weights should have the contact surfaces of their clutches kept clean and free from dirt or oil. These surfaces may be cleaned with gasoline and a stiff brush. The weights should be securely held by their arms and should be tightened at the first sign of looseness. The spring tension adjusting screws should be turned down tight when

properly adjusted and should be held in place by lock-nuts or other fastening devices.

The Delco ampere-hour meter, Figure 105, should have its contacts cleaned at long intervals. The only other care required is that the large hand be lifted up once every two weeks and turned twenty points in a clockwise direction. The hand should never be re-set past the number "70" on the dial, and if twenty points movement would do this, the amount of setting will have to be reduced.

STARTING TROUBLES

The starting system consists of the motor, the starting switch, the wiring and the driving parts. Electrical trouble may be present in the motor, switch or wiring and mechanical trouble may occur in the driving mechanism.

The troubles outlined under the heading of the dynamo in this chapter may also be found in the starting motor and their location and remedy will be cared for in the same way as in the case of the dynamo. The starting switch contacts may be making poor contacts because of wear, looseness or bending, or the contact surfaces may be dirty or pitted from sparking. The terminal connections of the large cables on the starting switch should be examined for loose wire strands, accidental grounds or short circuits, broken or loose fastenings. The wiring is subject to the same troubles as found in the charging or lighting circuits, but because of the heavy conductors and thick insulation used such faults will be of less common occurrence in the starting system than in other parts of the equipment.

The parts of the starter drive systems should be kept clean and sliding surfaces should be lubricated with heavy oil or by means of grease placed in the cups. This lubrication should be cared for at least every week if trouble is to be avoided. It may be found that drive shafts have become bent through binding or improper use of the starting pedal and in some cases it will be found that gear shifting and switch return springs are not heavy enough for the work to be done, especially on new cars before the parts have been fully worked in. Overruning clutches should be lubricated with vaseline or rather thin grease of good quality and the starting pedal should never be held in the starting position long enough to cause the clutch to be run at high speed. This will surely result in burning the grease and the final result will be a badly damaged or ruined clutch.

CHAPTER VIII

MAKES AND TYPES OF EQUIPMENT

Following the names of the well-known makes of automobile starting and lighting equipment will be found a brief description of the types of starting and lighting apparatus that have been made and marketed by these companies.

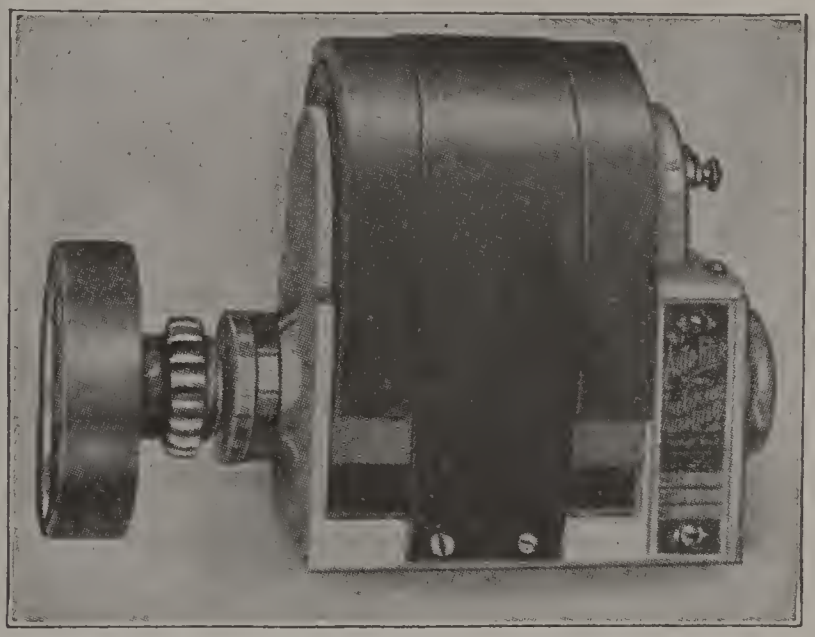


Figure 106.—Auto-Lite Dynamo with Constant Speed Governor.

AUTO-LITE

Early models of Auto-Lite equipment comprise a permanent magnet dynamo of the constant speed type, Figure 106, fitted with a slipping clutch governor at the drive end and carrying its electromagnetic cut-out underneath the magnets and just above

the armature housing. This machine has been superseded by types that have electromagnetic fields carrying a compound winding with the series coil arranged to oppose the shunt, Figure 107, thus forming a machine with reversed series regulation.

Auto-Lite dynamos have carried an ignition breaker and distributor in some instances, but other

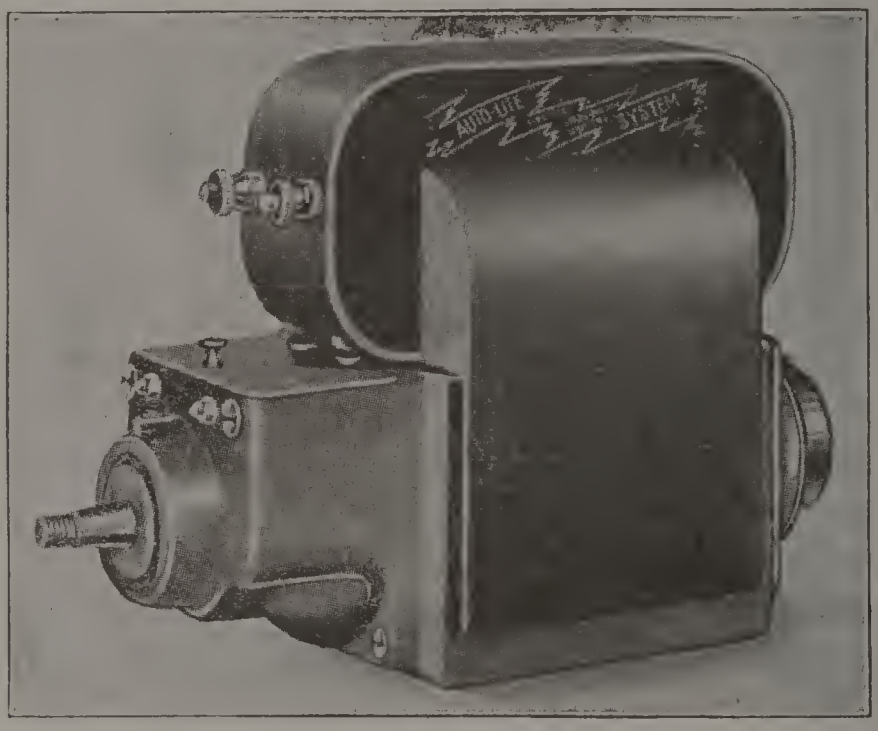


Figure 107.—Auto-Lite Dynamo Having Reversed Series Field Windings.

combinations, such as motor-dynamos, have not been used. The starting motors are straight series wound units in all cases and, together with the dynamos, operate at six volts.

DYNETO AND ENTZ

Until recently all machines of these makes have been compound wound motor-dynamos operating at a constant ratio of speed with the engine. The elec-

tric unit is directly connected to the engine, usually by means of a silent chain, and is placed in electrical connection with the battery by means of a hand-operated switch, no electromagnetic cut-out being employed. These single-unit machines, Figure 108, have been made to operate with either twelve or eighteen volts.

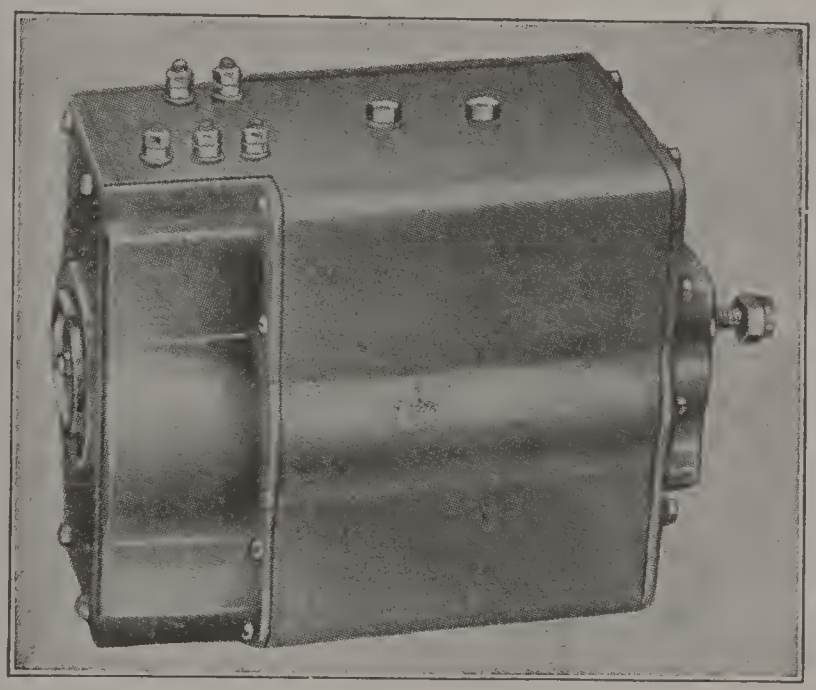


Figure 108.—Dyneto-Entz Motor-Dynamo.

A recent addition to the Dyneto line consists of a separate dynamo and a motor, both operating at six volts. The dynamo is connected with a separately mounted controller which contains an electromagnetic cut-out and a vibrating regulator that acts to insert a resistance in the field circuit when the amperage reaches a certain maximum determined by the adjustment of the regulator. The starting motor used with this system is a series wound machine conforming to the practice generally followed in such units.

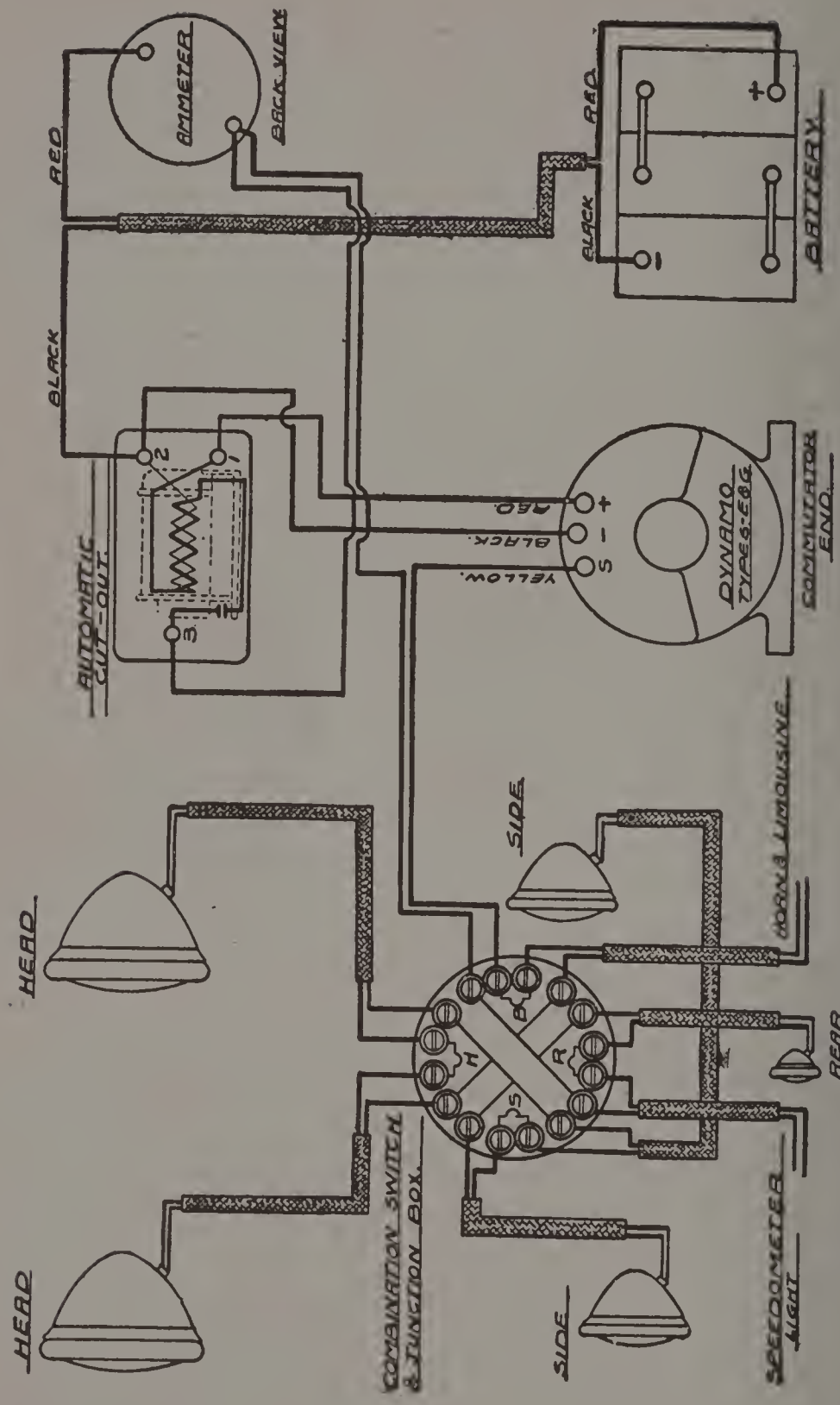


Figure 109.—Wiring for Gray & Davis System Having Constant Speed Dynamo.

GRAY & DAVIS

The first Gray & Davis equipments, Figure 109, included a compound wound dynamo fitted with a slipping clutch governor to limit the armature speed. The series winding of these machines carries the lamp current when any lights are in use, thus increasing the dynamo output in proportion to the load. An electromagnetic cut-out is mounted on the dash or at any other convenient point on the car, and the electrical devices may be wired on the ground return plan or by the use of a double-wire system throughout.

Later models of this make, Figure 110, use a dynamo of the shunt wound type having a vibrating regulator with field resistance and an electromagnetic cut-out mounted in one housing on top of or near the dynamo. The starting motors used with separate dynamos are of the series wound type in all cases and all units operate at six volts. Gray & Davis have recently added a single-armature motor-dynamo that carries the same form of controller as the separate dynamos just mentioned.

REMY

Remy equipment includes separate dynamos and motors, ignition dynamos, motor-dynamos, double deck machines and motor-dynamos with ignition parts mounted on the electric machine. With the exception of the twelve-volt motor-dynamo, all of the types make use of six-volt pressure for lighting, charging and starting. Either a third-brush system or else a vibrating regulator with field resistance have been used in a majority of installations. The third-brush machines, which class includes some of the double-

deck equipment as well as separate dynamos, make use of an electromagnetic cut-out carried on the dy-

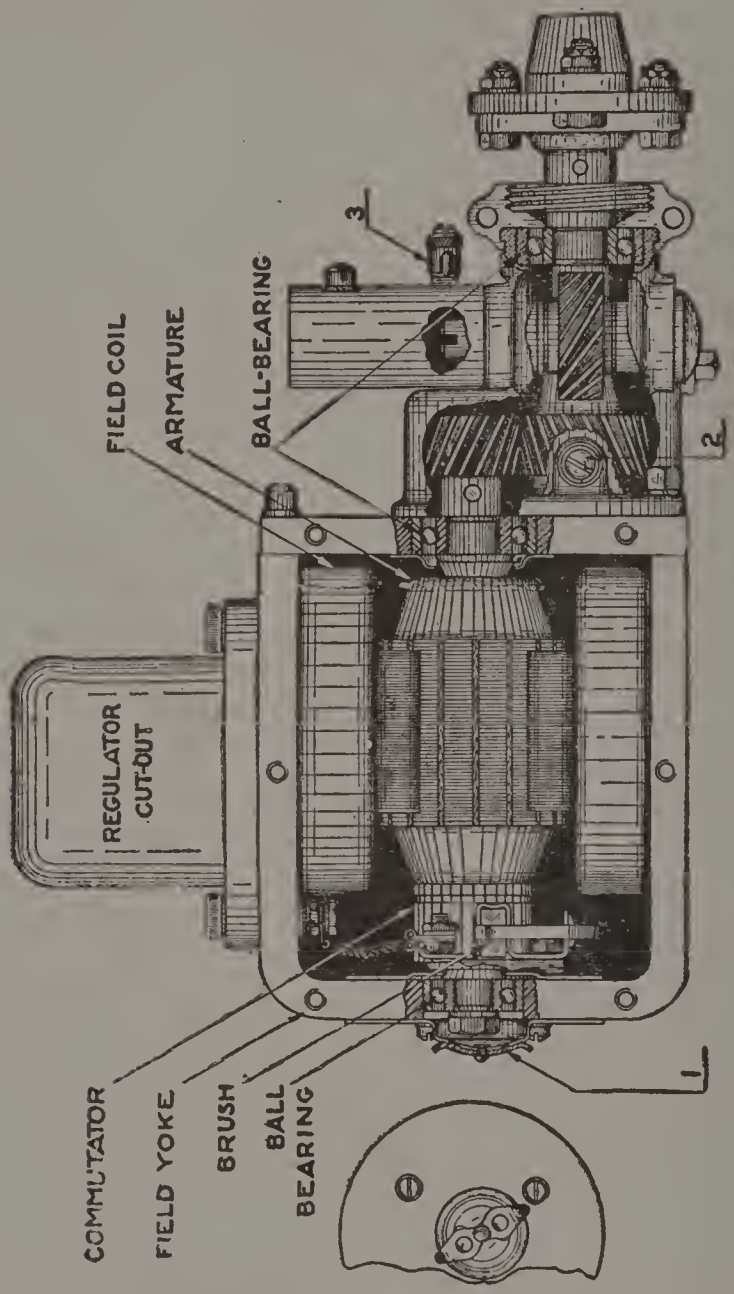


Figure 110.—Gray & Davis Dynamo with Vibrating Regulator and Cut-Out.

namo or mounted elsewhere on the car. The types using the vibrating regulator, Figure 111, combine the electromagnetic cut-out with the regulator in a

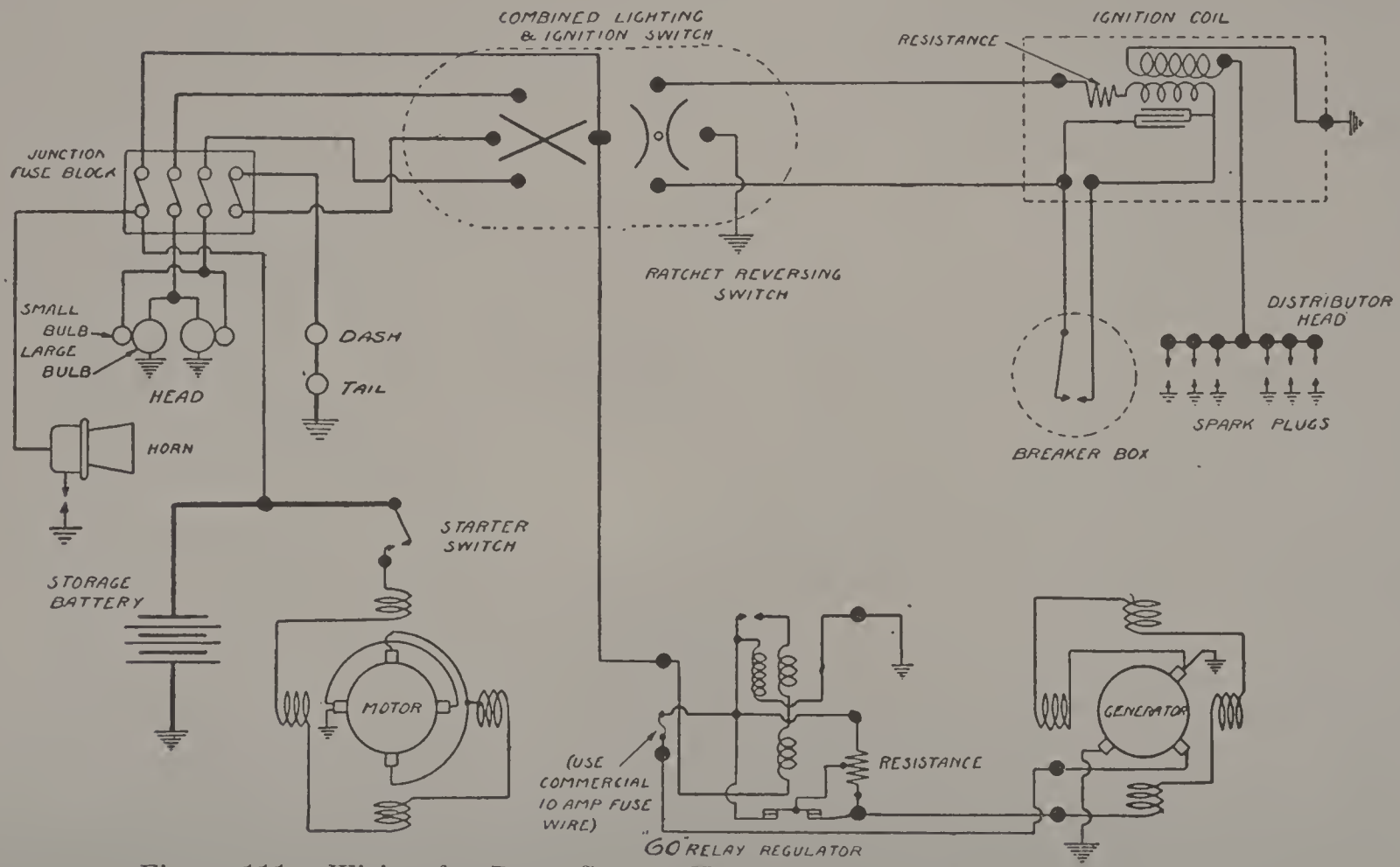


Figure 111.—Wiring for Remy System Having Vibrating Regulator and Cut-Out.

controller that may be carried above the dynamo or separately mounted.

Ignition-dynamos carry a breaker and distributor of the familiar magneto form at one end of the machine, and drive these parts from the extended armature shaft. In some cases a separate dynamo may be fitted with a vertical type of ignition breaker and distributor driven from the dynamo shaft. The starting motors are of the series wound type and may employ any one of several types of drive to the engine. The wiring for all units may be carried out on either the one or two-wire plan.

DELCO

The greater proportion of Delco equipment uses a compound wound motor-dynamo. Some of the more recent installations include separate dynamos having a shunt field winding and used in connection with a series wound starting motor. The earliest types consist of a single-armature motor-dynamo having one set of brushes for both starting and charging functions. These systems, Figure 112, are fitted with a twelve-cell battery of four sections, allowing twenty-four volts for starting and six volts for charging and lighting. These "6-24 volt" systems carry the ampere-hour meter regulator, described in Chapter V, and an electromagnetic cut-out.

All of the later motor-dynamo systems provide the single armature with two commutators, two windings and two pairs of brushes, one set of each being used for starting and the other for charging. These machines all operate at six volts and are built with the single-wire or grounded-return system in all cases. With some types of this class an electromagnetic cut-

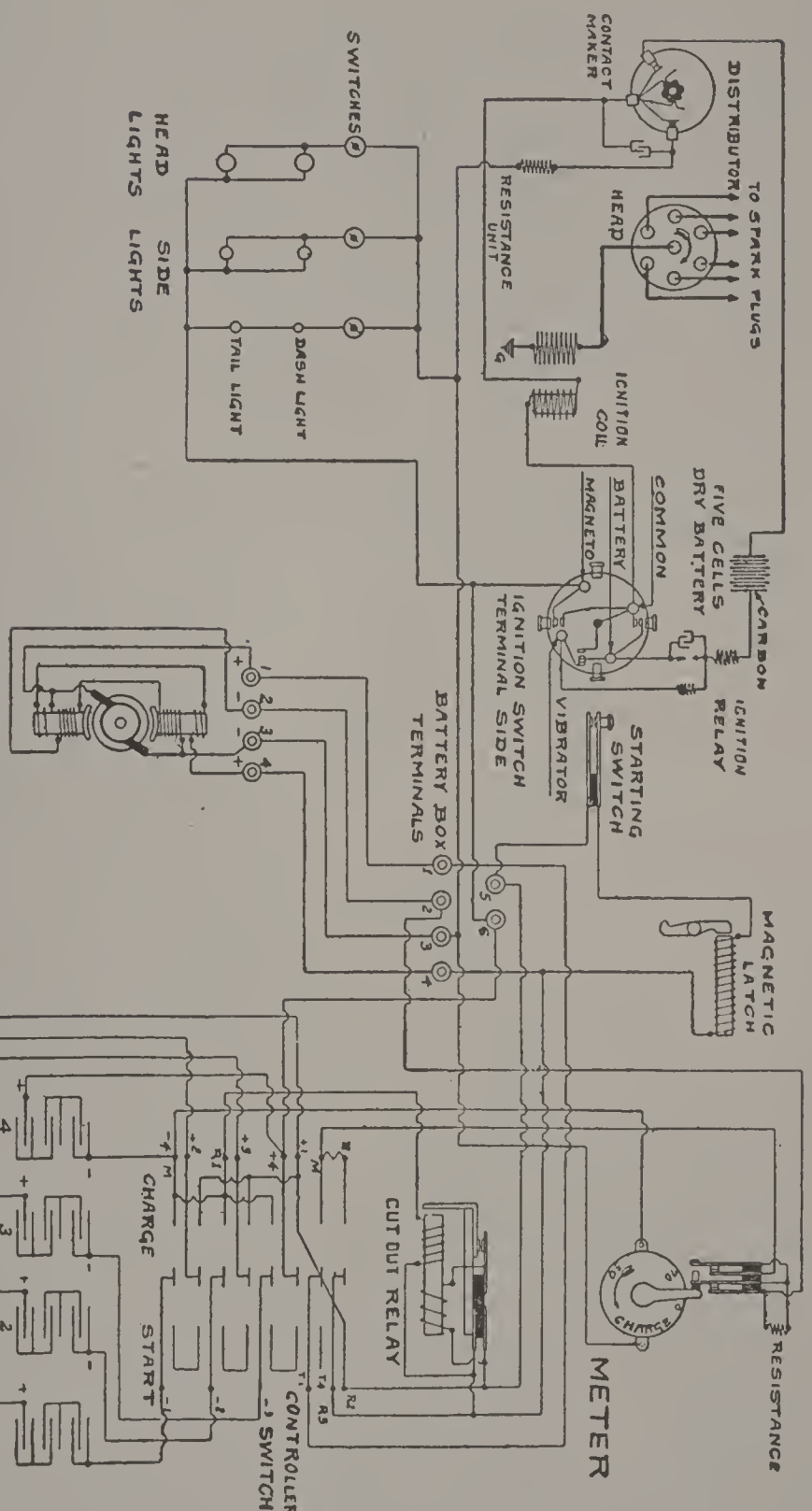


Figure 112.—Wiring for Delco System of the 6-24-Volt Type.

out is fitted, Figure 113, while others make use of additional contacts on the ignition switches for the purpose of connecting the motor-dynamo as a dynamo with the battery for charging. Regulating methods have included the reversed series system, a centrifugal governor, Figure 114, inserting a field resistance, a mercury-well type of voltage regulator or a third-brush control, Figure 115, for the shunt field current.

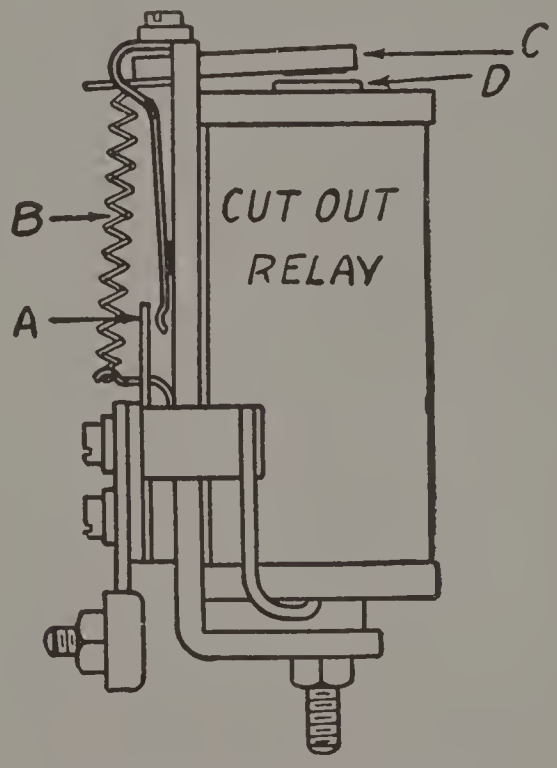


Figure 113.—Delco Cut-Out.

A—Contact Points. *C*—Magnet Armature.
B—Spring. *D*—Magnet Core.

DISCO

The most commonly used Disco equipment consists of a compound wound motor-dynamo direct connected to the engine by chains or gears. This unit is fitted with a controller comprising an electromagnetic cut-out and a vibrating regulator acting to insert a resistance in the shunt field circuit when the amperage

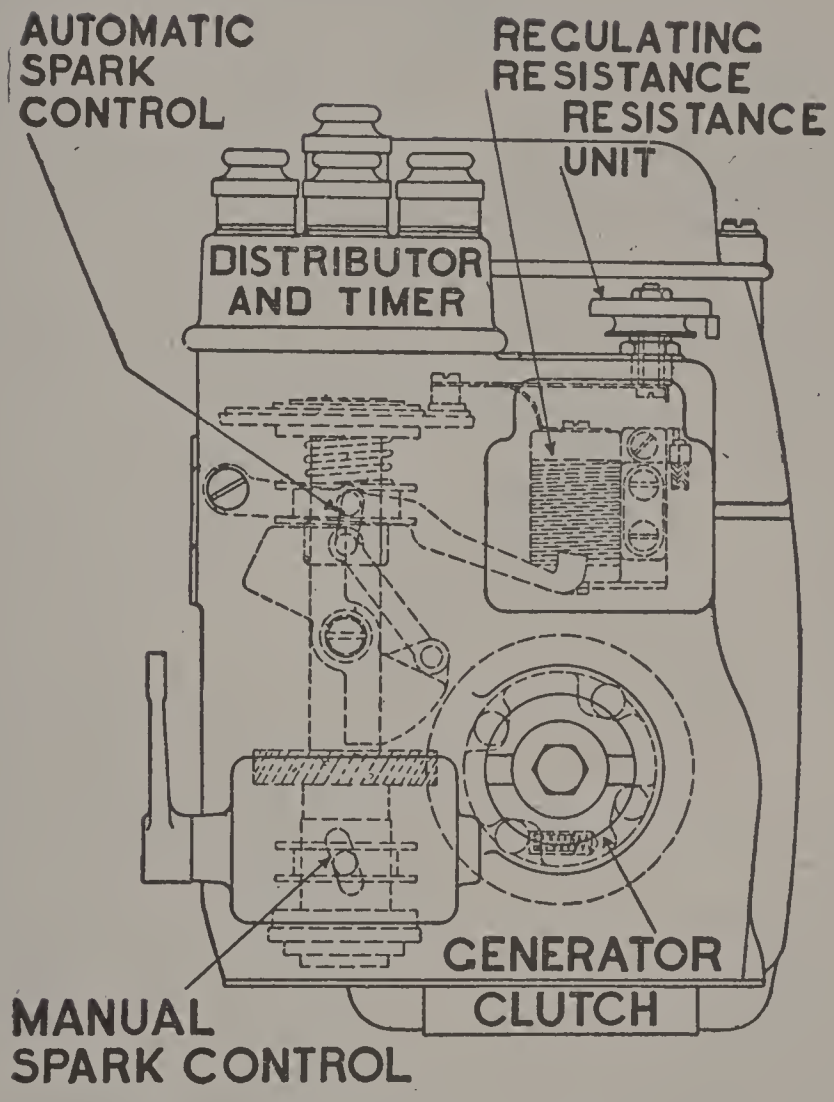


Figure 114.—Delco Centrifugal Governor and Field Resistance.

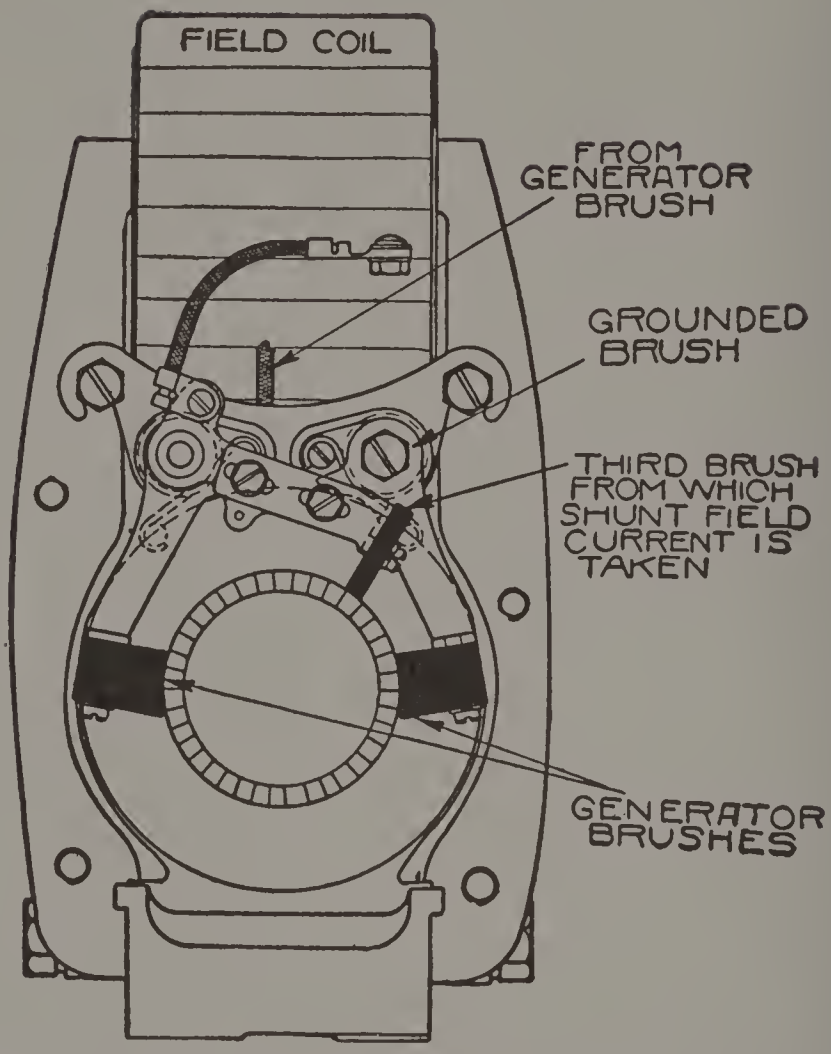


Figure 115.—Delco Third-Brush for Dynamo Regulation

is at the predetermined point. Disco systems of the kind described operate at twelve volts and make use of a single-wire connection for all circuits.

WESTINGHOUSE

Three distinct types of Westinghouse dynamos are in use. The form first adopted is a shunt wound machine with an additional bucking coil, the flow through which is lessened in proportion to the candle-power of the lamps lighted while the dynamo is running. These dynamos carry an electromagnetic cut-out at one end and may or may not be fitted with an ignition breaker and distributor at the other. Almost all dynamos of this class operate at six volts and cars using them generally are wired with a ground return system.

Twelve-volt motor-dynamos are also a part of the Westinghouse line, these machines being direct-connected to the engine at all times. The output is regulated by a third brush for the shunt field current and a separate electromagnetic cut-out may or may not be used.

Later models of Westinghouse apparatus include shunt wound dynamos with a self-contained or separately mounted controller consisting of an electromagnetic cut-out combined with a constant voltage vibrating regulator that inserts resistance in the field circuit when the voltage is at the correct point for battery charging. See Figure 116.

Separate starting motors are of the series wound type. They may be connected with the engine by means of a Bendix screw drive, by an electromagnetically operated starting switch and pinion shift, or by means of a two-contact switch with sliding gears

that are revolved by the current sent through the motor by the first contact of the switch, and after

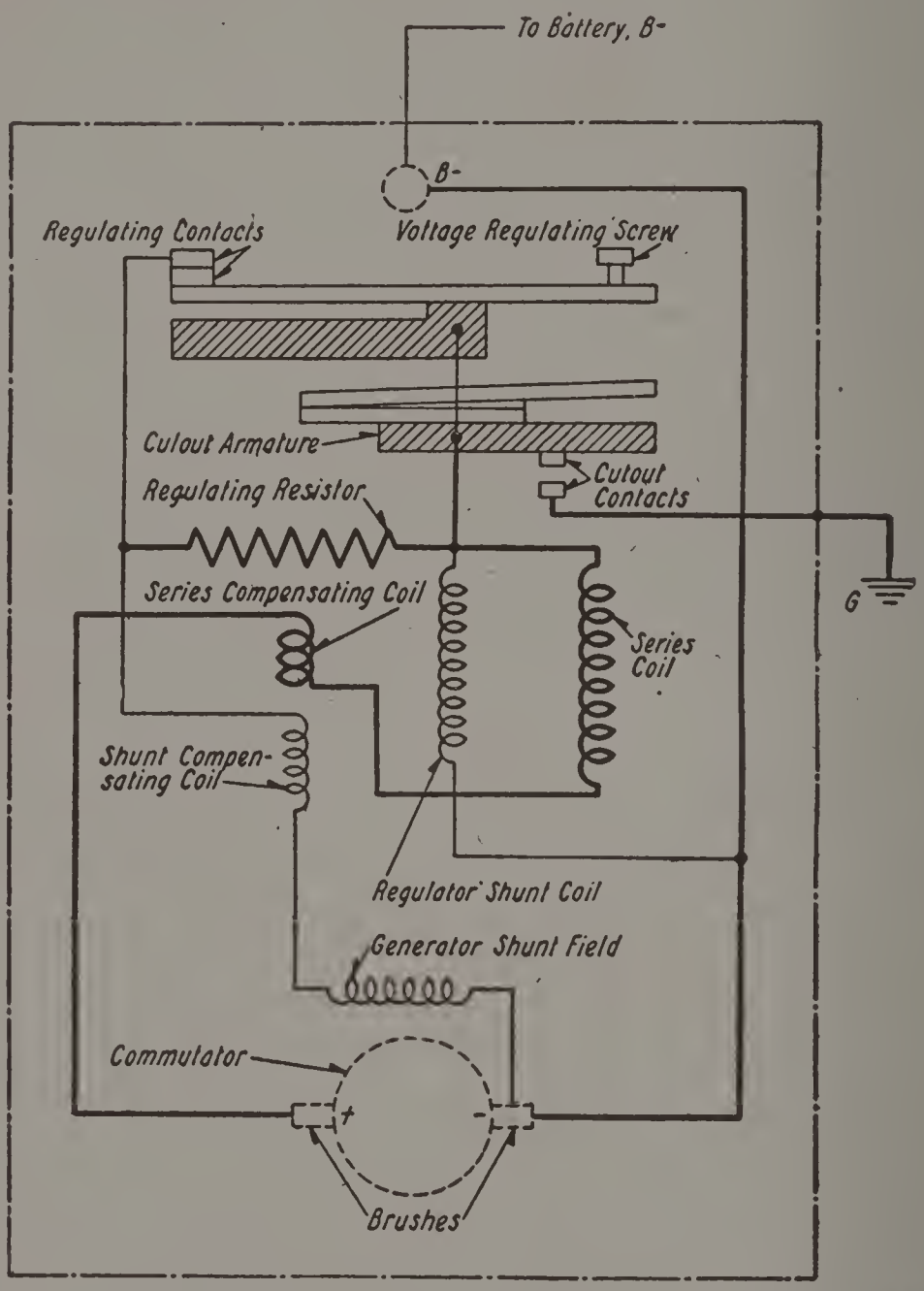


Figure 116.—Connections of Westinghouse Dynamo with Self-Contained Voltage Regulator and Cut-Out.

being meshed crank the engine with the full current allowed by the second switch position.

NORTH EAST

North East equipment consists of a motor-dynamo operating as a motor at twelve, sixteen or twenty-four volts and as a dynamo at six, eight or twelve volts. These machines carry a single armature and set of brushes and have compound wound fields. While some of the earlier models were connected to the engine through reduction gearing, a majority of these equipments are direct-connected and operate at a constant ratio of speed through silent chains or gears.

The dynamo housing encloses an electromagnetic cut-out and a vibrating regulator that acts to limit the amperage of the machine as a dynamo. Either the single or double-wire system is used.

U. S. L.

All of the systems furnished by the United States Light and Heating Corporation include a large size motor-dynamo mounted directly on the engine crank-shaft. The starting voltage may be either twelve or twenty-four, while lighting and charging is cared for at either six or twelve volts. Electromagnetic cut-outs have been used on all types and in the earlier models the cut-out is combined with an amperage regulator consisting of a series of carbon discs whose pressure on each other is controlled by the tension of a coiled spring which is allowed to increase or decrease through the opposing strength of an electromagnet in series with the charging lines. Later models of this make of apparatus control the output of the electric machine as a dynamo by means of field coils which either assist or oppose the shunt windings according to the speed and output of the machine, Figure 117.

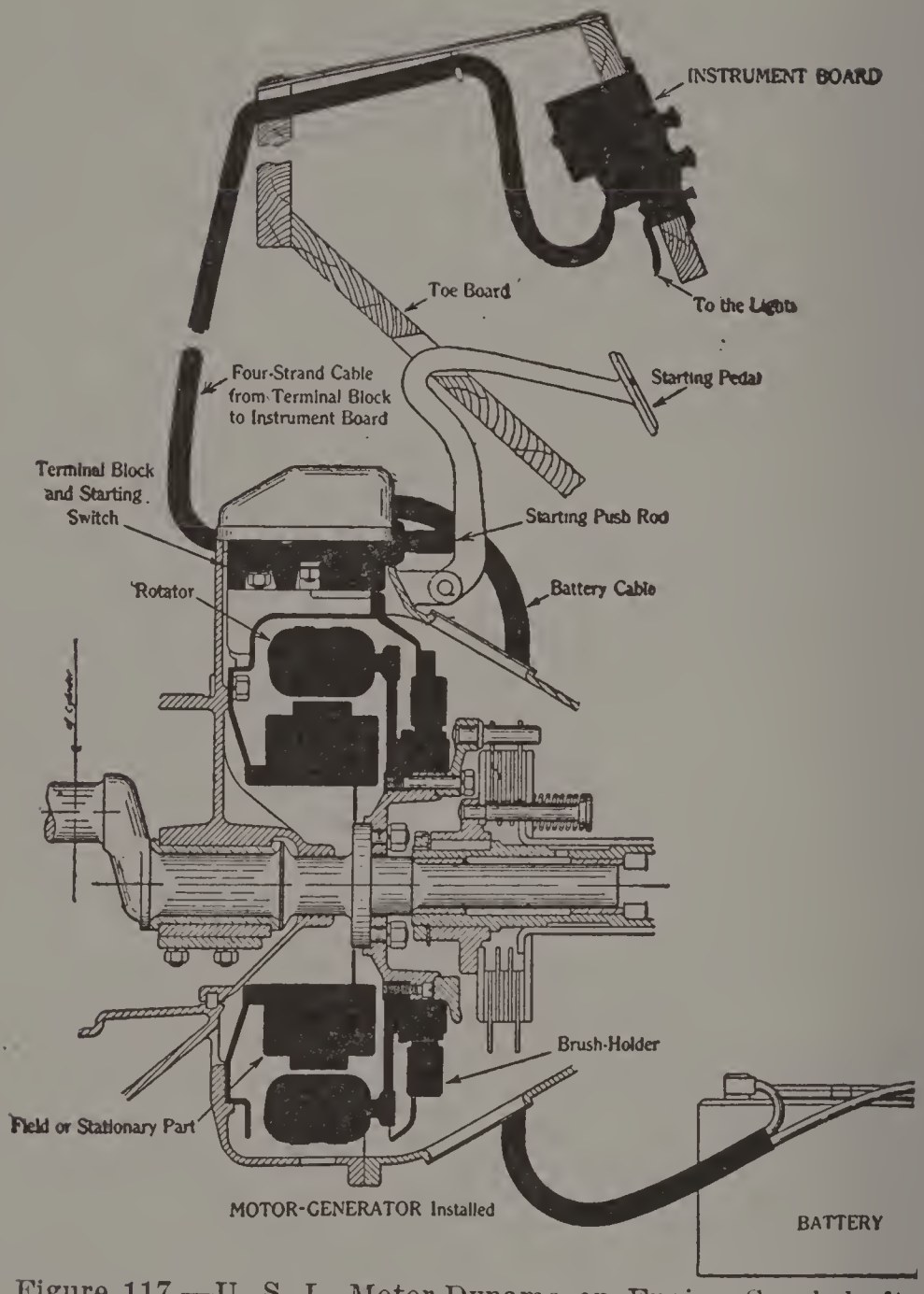


Figure 117.—U. S. L. Motor-Dynamo on Engine Crankshaft.

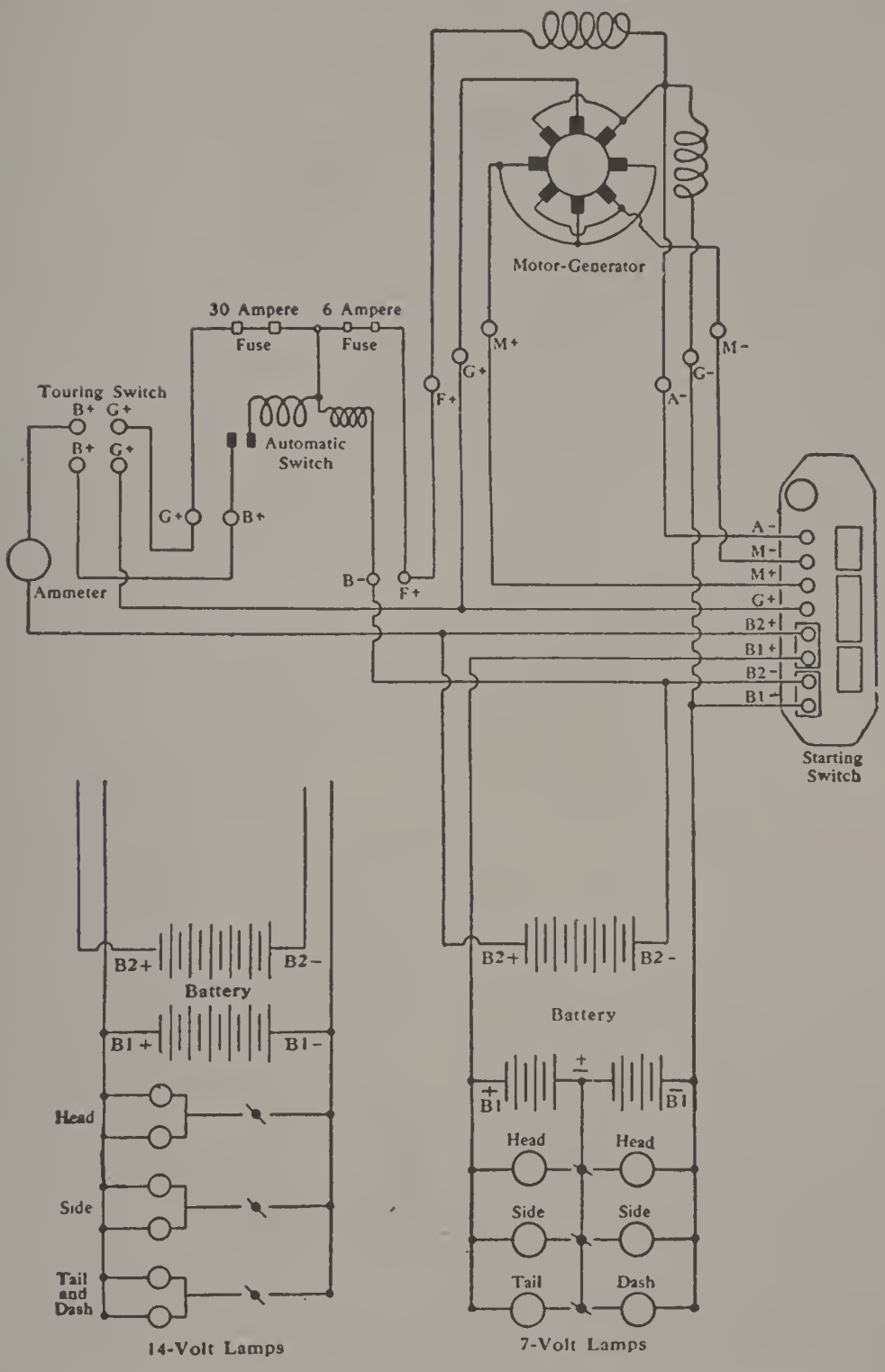


Figure 118.—Wiring for U. S. L. System Having Inherent Regulation.

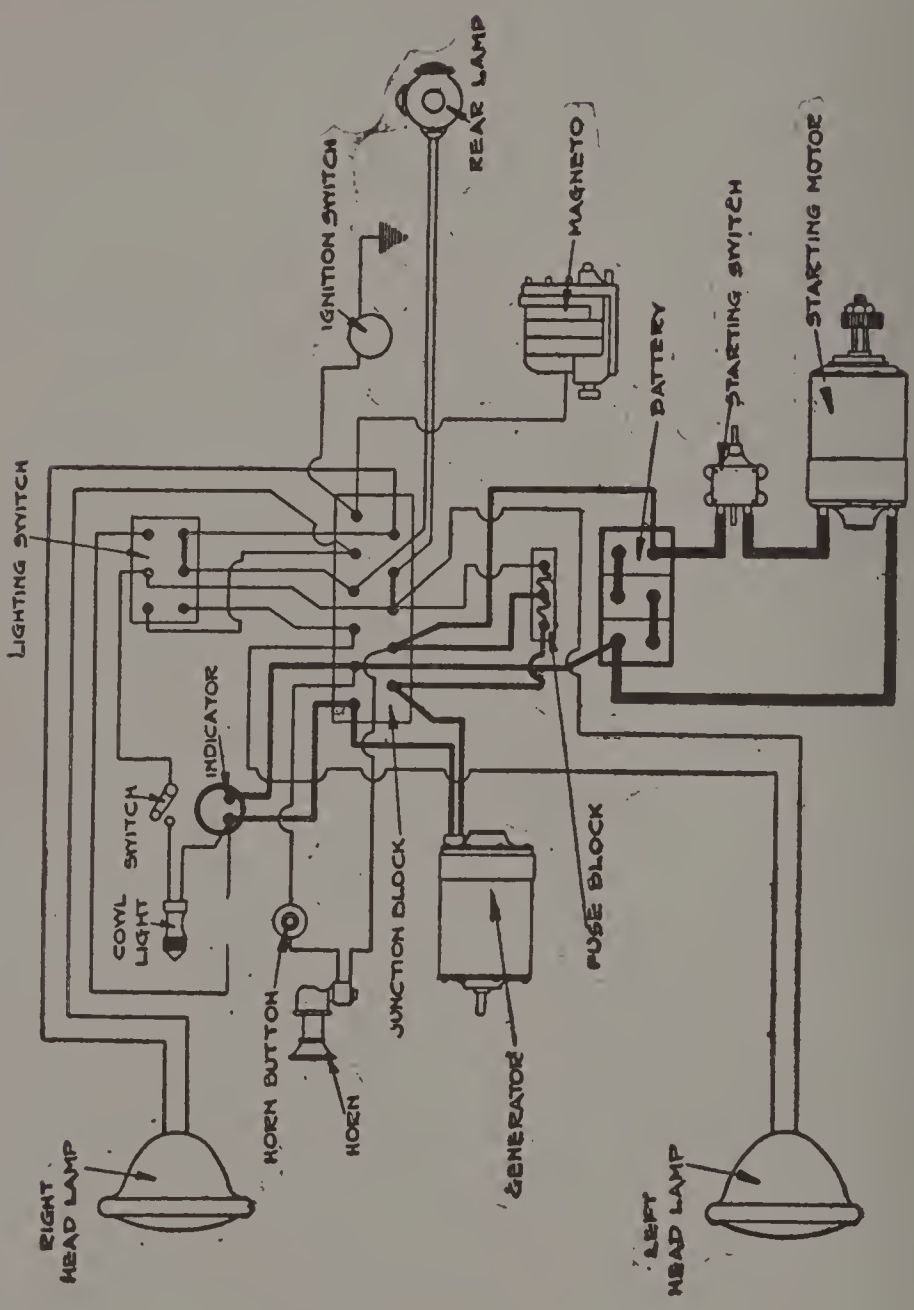


Figure 119.—Typical Wiring for Bijur System with Third-Brush Dynamo.

With the types that start at a high voltage, and use a lower pressure for charging and lighting, a form of commutating switch has been used which operates in an oil bath. Wiring for charging and starting may be on either the one or two-wire system, while lighting circuits may be of the one, two or three-wire type. See Figure 118.

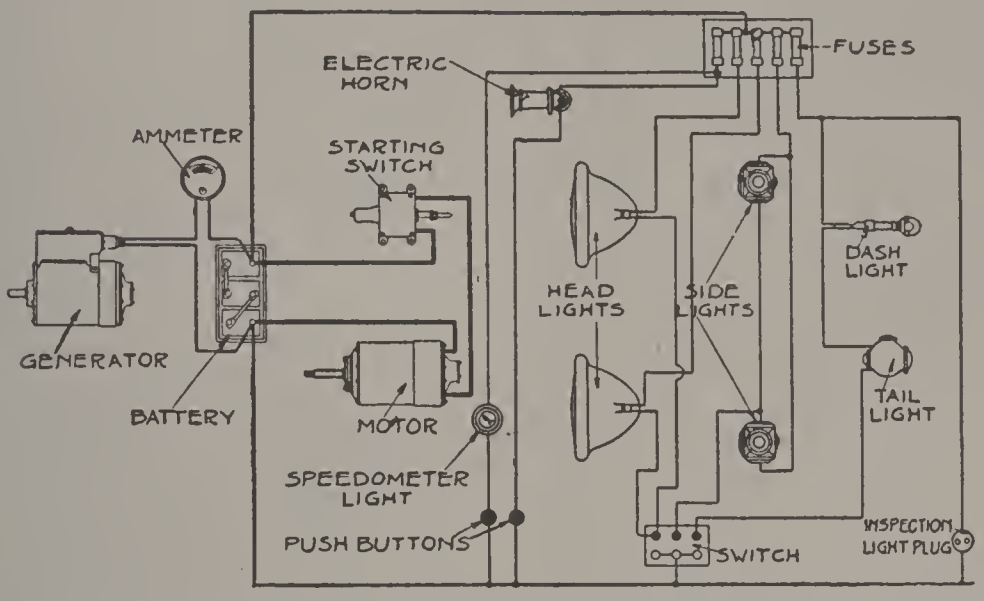


Figure 120.—Wiring for Bijur System with Constant Voltage Regulator.

BIJUR

Two types of dynamos and a motor-dynamo have been marketed. Both of the separate dynamos are of the shunt wound type, one operating on the third-brush principle, Figure 119, and the other being a constant voltage machine, Figure 120, controlled by the action of a vibrating regulator for the field resistance combined with an electromagnetic cut-out in a housing attached to the top of the dynamo. The third-brush dynamo is fitted with an electromagnetic cut-out carried inside of the dynamo case. Separate

starting motors are of the series wound type and all of the separate unit apparatus operates at six volts.

The motor-dynamo is a twelve-volt machine having direct connection with the engine through a silent chain. The output control is by third-brush action

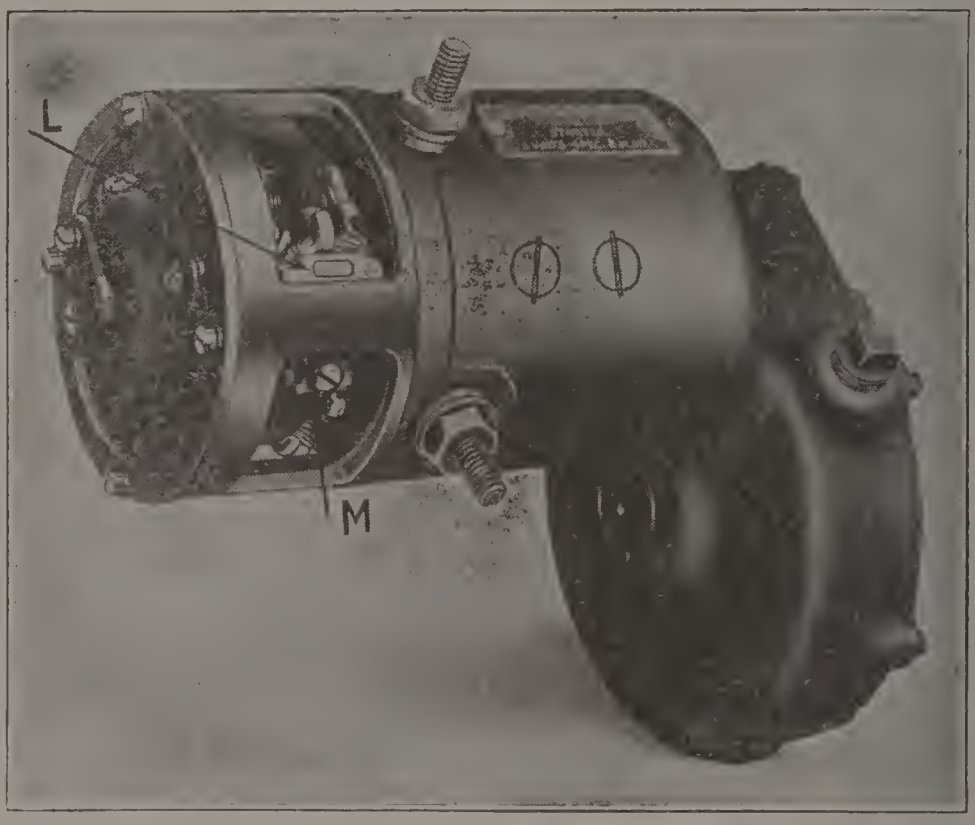


Figure 121.—Wagner Starting Motor. *L, M*—Brush Holders.

for the shunt field current and the electric machine is connected to the battery through a hand-operated switch without the use of an electromagnetic cut-out.

WAGNER

The first models of Wagner equipment include a motor-dynamo connected to the engine through a chain and planetary gearing. This machine acts as a starter at twelve volts pressure, and charges the battery at six volts. The commutating switch is mounted

on top of the unit and is in the same housing with an electromagnetic cut-out. This machine is a compound wound unit with third-brush regulation for the shunt field current.

Later models of Wagner equipment make use of separate dynamos and motors, the dynamos being shunt wound with third-brush regulation, and the motors, Figure 121, being of the usual series wound form. The operating voltage for these separate unit installations may be either six or twelve. Wiring is either single or double throughout.

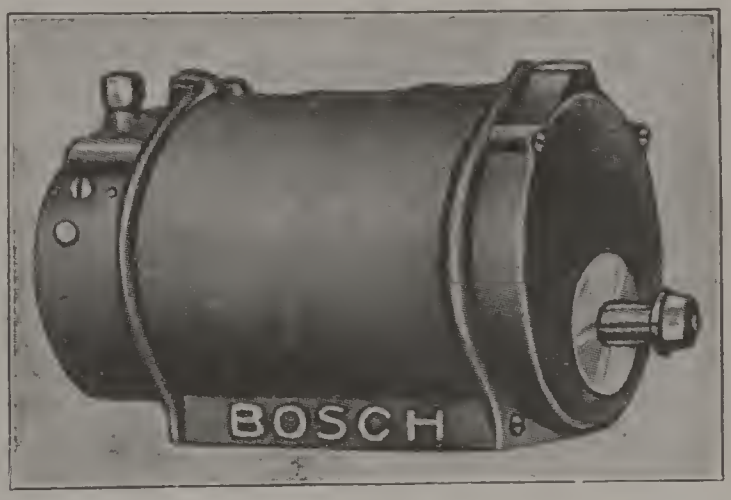


Figure 122.—Bosch Dynamo for Use with Voltage Control.

BOSCH AND RUSHMORE

The original Rushmore dynamo, and some of the newer models of Bosch dynamos make use of the iron wire controlled bucking field coil for regulation. Otherwise these machines are of the shunt wound type operating at either six or twelve volts and connected by either a double or single wire system. An electromagnetic cut-out is used in all cases, this unit being mounted on the dynamo or on a separate panel.

One type of Bosch dynamo, Figure 122, is a con-

stant-voltage machine having a regulator whose resistance is composed of carbon particles and mica. This regulator is carried in a housing with the elec-

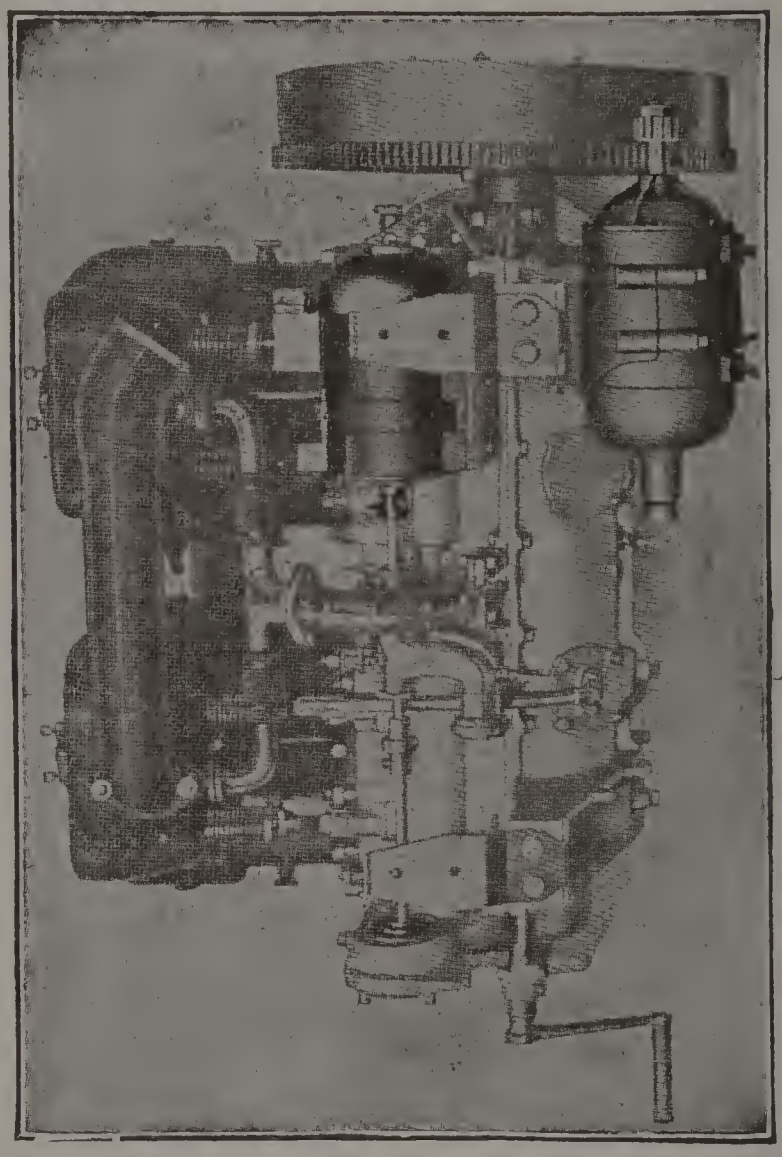


Figure 123.—Arrangement of Rushmore Units on Engine.

tromagnetic cut-out and a voltmeter. These machines are of the twelve-volt type.

Rushmore type starting motors are used with any of the dynamos just described. This form of starting motor, Figure 123, causes the drive pinion to mesh with the flywheel gear by means of the end motion of

the armature shaft induced through the pull of the field magnets, this action having been described in Chapter VI.

SPLITDORF

Splitdorf equipment includes a motor-dynamo, Figure 124, operating at twelve volts for both starting

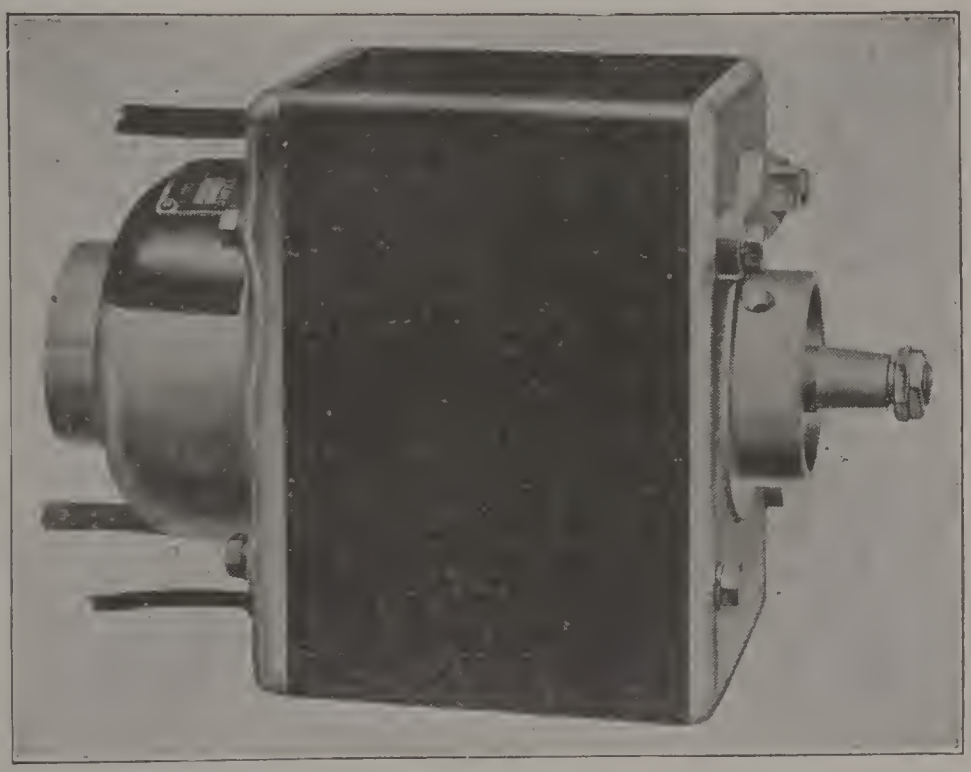


Figure 124.—Splitdorf-Apelco Motor-Dynamo.

and charging or else at twelve volts for starting and six volts for charging. In any case the unit is direct-connected to the engine by means of a silent chain and operates at a constant ratio of speed with the engine.

The electric unit is compound wound and is connected to the battery by means of a separately mounted electromagnetic cut-out having a target arranged to show the words "OFF" or "ON" accord-

ing to whether the cut-out is open or closed respectively.

The straight twelve-volt system makes use of a single-contact starting switch, while the six-twelve volt system uses a commutating switch to make the proper connections between battery sections and motor-dynamo. Either one or two-wire systems may

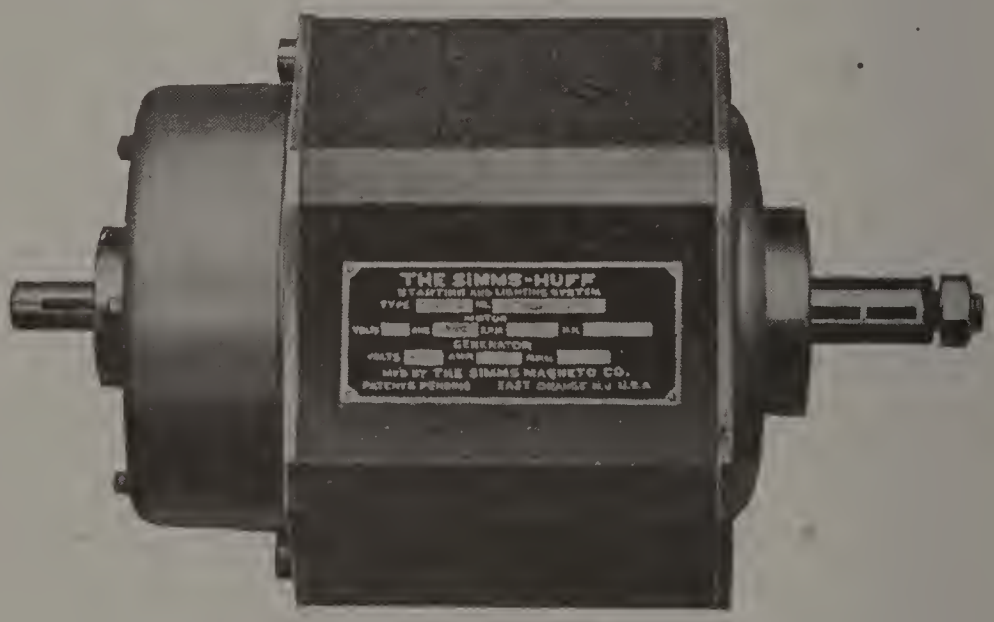


Figure 125.—Simms-Huff Motor-Dynamo.

be used, although the one-wire type is the one generally adopted.

SIMMS-HUFF

This equipment uses a compound wound motor-dynamo, Figure 125, driven as a dynamo from the engine through a flat belt and driving the engine as a starting motor through sliding gears. A two-section battery is connected with the electric machine at twelve volts for starting and six volts for charging, the necessary changes being accomplished with a commutating switch.

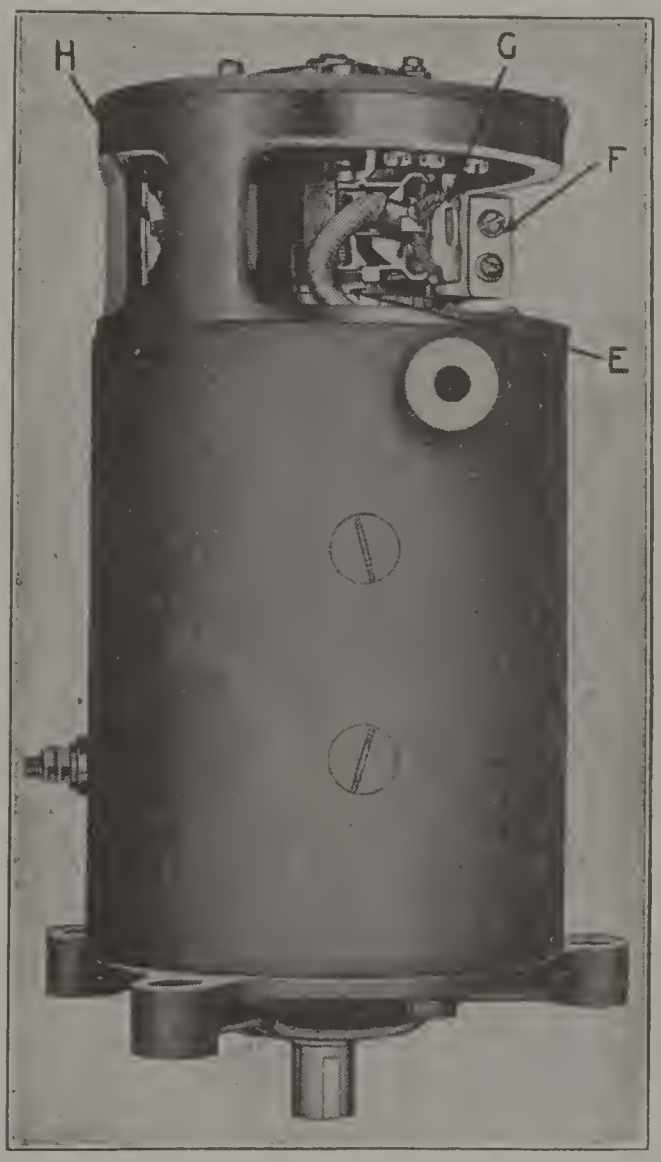


Figure 126.—Allis-Chalmers Motor-Dynamo.

E—Commutator. *F* Brush Holder. *G*, *H*—Pig-Tails.

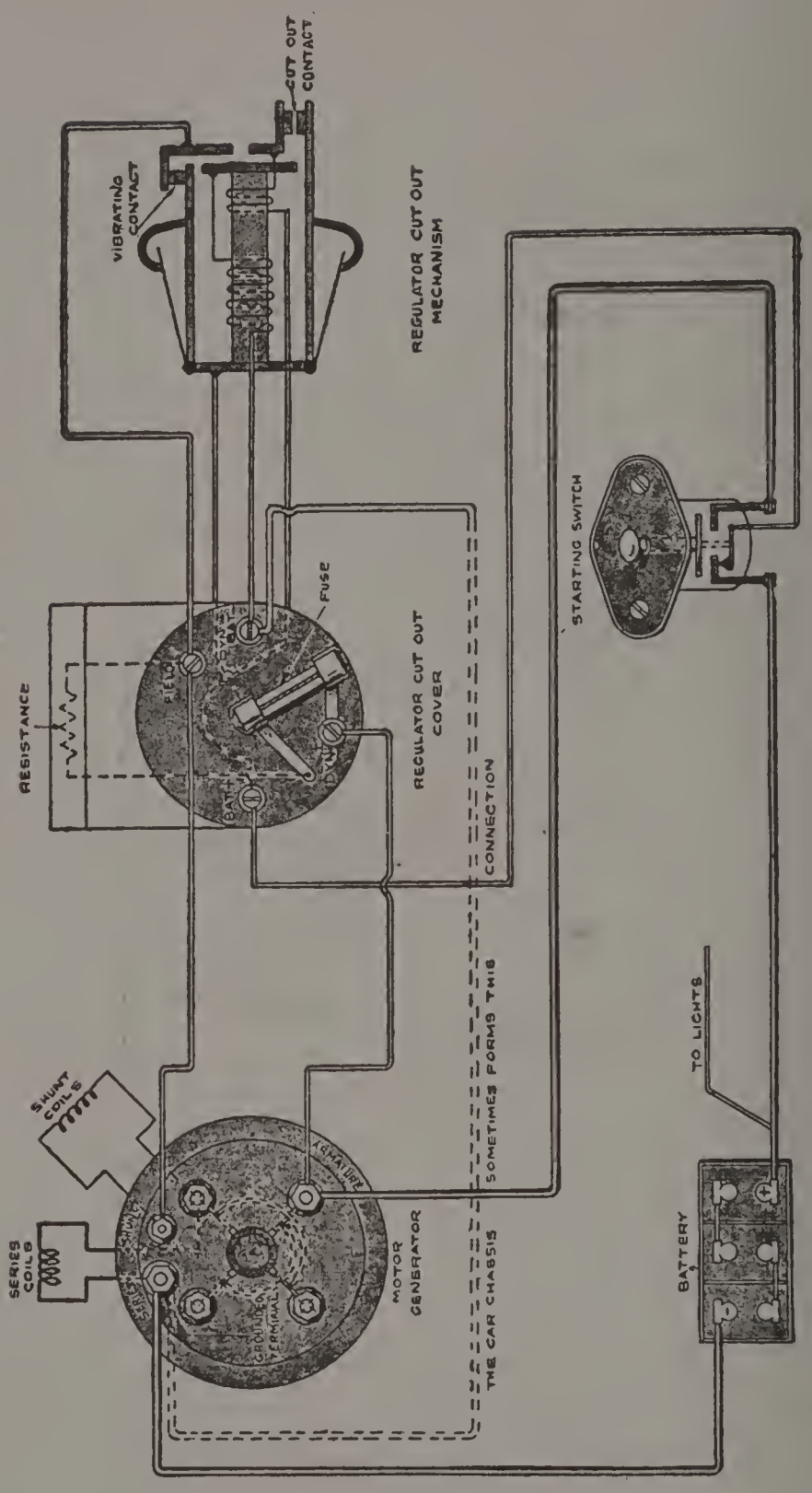


Figure 127.—Wiring for Allis-Chalmers Motor-Dynamo System.

An electromagnetic cut-out combined with a vibrating regulator acting to insert field resistance is employed to control the action of the machine as a dynamo. Further regulation is provided by the reversed series action of the series field winding while the unit is generating. The one-wire system with grounded return is used throughout the installation.

ALLIS-CHALMERS

The Allis-Chalmers equipments in general use consist of a compound wound motor-dynamo, Figure 126, operating at six volts under all conditions and directly connected with the engine so that it runs at a constant ratio of speed. The electric machine is connected with the battery for charging by means of an electromagnetic cut-out carried in the same housing with a vibrating regulator that inserts resistance in the shunt field when the correct amperage has been reached. All circuits are of the single wire type. See Figure 127.

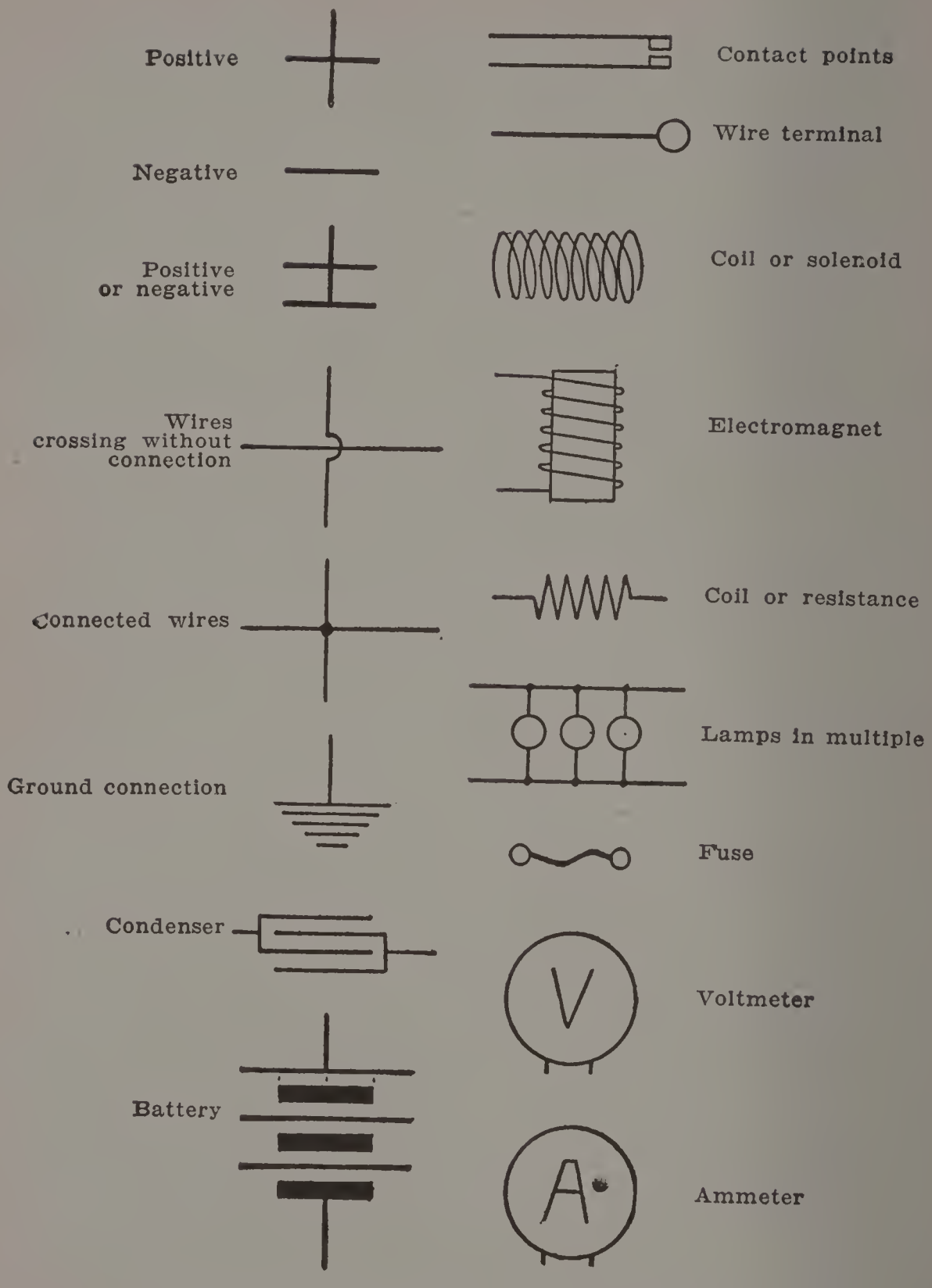


Figure 128.—Symbols Used in Wiring Diagrams.

CHAPTER IX

ELECTRICAL WORDS AND TERMS

A. C.—An abbreviation for alternating current. See *Current, Alternating.*

Accumulator.—A storage battery. See *Battery, Storage.*

Acid, Battery.—Chemically pure sulphuric acid having a specific gravity of about 1.835, suitable for use in making storage-battery electrolyte for lead cells.

Adapter.—A small threaded sleeve designed to screw into a candelabra base so that a miniature bulb may be used.

Ammeter.—An instrument for measuring the rate of flow of electric current directly in amperes.

Amperage, Constant.—Descriptive of a form of regulation which allows the dynamo current to rise rapidly to a predetermined maximum and then causes the dynamo to maintain this value of current without much rise or fall at all higher speeds.

Ampere.—The unit of current flow. Corresponds to gallons per minute in measurement of water flow. The rate of flow caused to pass through a circuit whose resistance is one ohm by an electrical pressure of one volt.

Ampere-Hour.—The quantity of electric current that flows during one hour through a circuit in which one ampere is passing. Equals 3,600 coulombs. Used in measuring the capacity of storage batteries, in which case a battery having a capacity of 80 ampere-hours would be capable of maintaining a flow of eight amperes for ten hours, ten amperes for eight hours, or any other combination of hours and amperes which multiplied together will result in eighty.

Ampere Turn.—One complete turn of a conductor in a coil through which one ampere is passing. The amperage multiplied by the number of turns in a coil gives the number of ampere-turns in that coil. The ampere turns of a coil determine its magnetic strength and the same strength

will always be developed by the same number of ampere turns whether they result from a large number of turns and few amperes or large amperage and few turns.

Arc.—The flash or spark between two parts of a conducting path through which current is flowing when these parts are caused to separate. Seen at cut-out contacts, regulator contacts, dynamo and motor brush contacts on their commutators, etc.

Armature.—A piece of iron or steel so placed that it is in the field of a magnet or is acted upon by the lines of force of a magnet.

Armature, Dynamo or Motor.—A part of the machine which consists of an iron core on which is wound coils of wire. In the case of a dynamo, the movement of these coils through the magnetic field causes voltage to be generated and a flow of current to result. In the case of a motor the operating current, or part of it, is sent through the armature windings and the result, together with the effect of the fields, causes the reaction which results in delivery of power from the motor. The armature is usually the part of the machine that revolves, although in some dynamos the armature is stationary and the fields are revolved.

Armature, Drum.—A form of armature in which the windings pass from end to end of the iron core and around the ends. The core is usually a solid mass of iron of cylindrical shape.

Armature, Magnet.—A small piece of iron or steel mounted on a movable holder and carried near one end of an electromagnet. The armature is attracted to the magnet whenever current flows through the magnet windings. Attached to the movable arms of cut-outs, regulator vibrators, circuit breakers, etc.

Armature Reaction.—A term often used to describe the effect of the rotating armature core in carrying the lines of force of the field part way around in the direction of revolution while the dynamo is in operation. With stationary brushes the voltage between the points on the commutator against which the brushes bear will vary with the extent of this effect present. Utilized in "third brush regulation."

Armature, Ring.—Sometimes called a "Gramme" ring armature. An armature whose windings are placed around a circular or ring-shaped core.

Ballast Coil.—The length of iron wire inserted in the charging circuit of Rushmore and some Bosch-Rushmore dynamos which acts to send a part of the current around the bucking field coil with excessive increase of current generated.

Bar, Commutator.—See *Segment.*

Battery, Storage.—A number of storage cells placed together as a single unit and arranged to be connected with each other to give the desired voltage for the circuits to which the battery is attached.

Bayonet Base.—A form of lamp bulb socket of cylindrical form and hollow with two or more lengthwise slots open at the lamp end and ending in a turned over or hooked portion of the slot at the other end. The corresponding bulb base carries two or more projecting pins designed to slide down into the slots and then engage with the hooked portions by giving the bulb a part of a turn. The two parts are then held together by the pressure of small plungers or flat springs in the socket portion.

Bendix Drive.—A form of starting motor drive which causes a pinion carried on a threaded shaft attached to the armature shaft to revolve on this threaded shaft and because of its travel along the threads to mesh with teeth on the rim of the engine flywheel so that the power of the starting motor is applied to crank the engine.

Brush.—Pieces of some conducting substance, usually carbon composition or copper, which bear on a moving surface such as a commutator or the segments of a rheostat and which collect or distribute current.

Bucking Coil.—A winding placed on the field magnets of a dynamo and which opposes the strength of the shunt field winding whenever current is passed through the bucking coil. Used to obtain regulation of dynamo output.

Buckling.—An action that takes place in the plates of a storage cell which causes the entire plate to bend or warp.

Bulb.—The glass part of an incandescent lamp. Often used to designate the glass bulb with the filament and base.

Bus-Bar.—A strip of copper or brass which carries a number of terminals to which conductors and wires of an electric system may be attached.

Cable.—A conducting wire with its insulation. Usually applied to such wires when they are of comparatively large size.

Calibrate.—To determine the accuracy of the indications given by an electrical instrument such as a voltmeter or ammeter and to note the error, if any, between the scale divisions on the instrument being calibrated and another one of known accuracy or with currents and voltages of known value. Usually employed to designate the operation of correcting the working of an instrument so that its indications are correct.

Candelabra.—The name given to the larger of the two sizes of screw bases used for lamps employed in car lighting.

Candlepower.—The unit used in measuring the light given by any source of illumination. One candlepower is the light given by a standard candle made to burn a certain definite quantity of spermaceti each minute and of standard dimensions and construction.

Capacity, Battery.—The number of ampere-hours discharge that may be secured from a storage battery. It is affected by the rate of discharge in amperes, by the voltage, specific gravity and condition of the plates in the cells, by the temperature of the battery and by many other factors.

Carbon.—A chemical element. Found in graphite, charcoal, diamonds and fuel substances generally.

Cell, Storage.—A unit consisting of several positive plates and several negatives with plates of like polarity connected together and with the whole set immersed in a bath of electrolyte and enclosed by a jar of insulating material. A storage cell gives a voltage of approximately two, regardless of its size, but the capacity depends on the quantity of material in the plates and the design of the battery parts.

Charge.—The action of sending a flow of current through a storage battery so that a chemical change is caused to take place which results in the ability of the battery to deliver current.

Circuit.—The complete path through which a current flows from the time it leaves the source until it returns to the source. A circuit must always consist of three parts when employed in electrical equipment; namely, the source which may be the dynamo or the battery, the conductors which consist of wires and connections for both positive and negative sides, and the receptive or current-consuming devices which may consist of the lights, starting motor or other equipment. A circuit must always start with and end with the source, and if any portion of the circuit is incomplete there can be no flow of current at any point or in any part of the circuit.

Circuit Breaker.—A device consisting principally of electromagnets and current-carrying contacts which is designed to open a circuit whenever the current flowing through it exceeds a certain value. This name is often applied to a cut-out, although a circuit breaker and a cut-out do not perform similar duties.

Circuit, Closed.—A circuit that is complete from the source to the current-consuming devices and from these devices back to the source and through which a current can flow.

Circuit, Grounded.—A circuit which is completed through the metal work of the car. The metal work takes the place of any other conductor for a certain portion of the path.

Circuit, Open.—A conducting path which is not complete from the source of current to the current-consuming devices and back to the source. No current can flow through a circuit that is open at any point in its path.

Circuit, Short.—A connection between two wires or conductors of opposite polarity that allows the current flowing from the source to complete a path back to the source without going through the current-consuming devices or without doing the work that it should were the current forced to pass through the whole circuit. Should a current-carrying conductor of one polarity come into contact with the frame or metal work of the car when this metal work forms a part of the circuit of opposite polarity from the first conductor, a form of short circuit called a "ground" is formed.

Clips, Fuse.—The small spring or screw holders which carry a cartridge fuse.

Clutch, Overrunning.—A device consisting of two parts, one driven from the starting motor and the other driving to the engine to be cranked, with these parts arranged to be held together by wedging rollers when the starting motor drives the engine, but so arranged that the rollers will release and allow the engine to run free when its speed exceeds that at which the starting motor can drive it.

C. O. D. Indicator.—See *Indicator.*

Coil.—One turn or a number of turns of wire surrounding a central core usually of iron or wound on a support that allows a hollow space through the center of the coil.

Coil, Compensating.—The name applied to one of the windings on one of the field magnets in the U. S. L. motor-dynamo. The function of this winding is to control the dynamo output by assisting the shunt field at low speeds and by opposing the shunt at high speeds.

Commutator.—The series of segments attached to the armature windings of a direct current dynamo or motor and on which the brushes bear. The segments pass underneath the brushes at such a time that the alternating current produced in the armature windings is changed into a direct current for use in the outside circuits.

Compound Winding.—See *Winding, Compound.*

Condenser.—A number of sheets of some thin conductor, usually tin foil, placed one on top of another but separated by some insulating material such as mica or waxed paper. The sheets of conductor are connected in two sets, every alternate sheet being fastened to one lead and those between to the other lead. The condenser is placed so that one lead attaches to one current-breaking contact while the other lead attaches to the other contact. A part of the electricity that would ordinarily result in a spark at the time the contacts separate, passes into the condenser and remains there until the contacts again close, at which time this electricity from the condenser adds its effect to that passing through the contacts.

Conductor.—Any material or substance through which the electric current can pass with ease. All metals and many liquids are good conductors.

Conductivity.—The opposite of resistance. A measure of the readiness or ease with which current can pass through a conductor. The higher the resistance to passage of current becomes, the less will the conductivity become.

Conduit.—A tubular protecting covering for electric wiring generally made from metal and either flexible or rigid.

Connector.—A device for completing one or both sides of a circuit by means of pin plungers carried by one part of the connector and designed to fit into holes in the other part of the device. The ends of the circuit wires are fastened to the pin at one side and to the metal lining of the hole at the other.

Constant Amperage or Voltage.—See *Amperage, Constant*, and *Voltage. Constant.*

Contacts.—Small pieces of heat and spark-resisting conductor, usually metal or carbon, that carry the current flowing through a circuit when two of the contacts are touching each other and which act to break the circuit when they are drawn apart.

Control.—The action of limiting the current delivered from a dynamo and of preventing the current in the charging circuits from taking improper paths. Control is effected by the current regulating system and by the cut-out.

Controller.—An electromagnetic cut-out and a current output or voltage regulating device carried in one case or combined with each other so that some of their parts function with both units.

Core.—The iron form upon which coils of wire are carried or wound in forming electromagnets, dynamo or motor field magnets, armatures, etc.

Corrosion.—The action of acids or alkalies upon metal or the substance formed by this action. Found on the terminal connections of storage batteries and between the metal of their grids and the active material of the plates.

Coulomb.—A unit which measures electrical quantity and whose value is 1/3600 of an ampere-hour. A coulomb is the quantity of electricity that passes through a circuit in one second if the rate of flow is one ampere.

Current.—The rate of flow or the quantity of electricity that is passing through a circuit. Current flow is meas-

ured in amperes and is increased with increase of pressure or voltage and is decreased by increase of resistance.

Current, Alternating.—A current which reverses its direction of flow or its polarity at regular intervals. Alternating current is generated by all dynamos and in direct current dynamos the alternating current is changed to direct current by the commutator.

Current, Continuous.—Direct Current (which see).

Current, Direct.—A current which always flows in the same direction through its circuit and which would cause conductors through which it flows to remain of the same polarity at all times.

Current, Eddy.—Currents produced in the iron cores of the armature and field magnets of motors and dynamos by the motion of these parts in a magnetic field or by the motion of magnetic lines of force about them.

Current, Pulsating.—A current whose value rises and falls suddenly.

Cut-in.—The closing of the charging circuit by the cut-out when its contacts come together. Cut-in time means the engine or armature speed at which this action takes place.

Cut-out.—A switch through which the charging circuit from dynamo to battery is completed. When the cut-out is open there can be no flow through the charging circuit, either from dynamo to battery or from the battery through the dynamo. When the cut-out is closed a current may flow in either direction and the direction of flow will be from the unit having the higher voltage to the one of lower voltage.

Cut-out, Electromagnetic.—A cut-out switch whose current-carrying contacts are closed by the magnetic strength of an electromagnet through the windings of which current flows from the dynamo and whose strength is determined by the voltage generated by the dynamo. The contacts are opened and held open by the action of a spring or by the force of gravity which opposes the electromagnet.

Cut-out, Hand or Manual.—A cut-out switch operated by the driver of the car and so connected with either the ignition or starting switches that the cut-out will be open whenever the engine is idle or the ignition turned off and

will be closed by the closing of the starting switch or by the closing or turning on of the ignition switch.

D. C.—Direct Current. See *Current, Direct.*

Discharge.—The flow of current from a storage battery to and through the outside circuits. Any flow which causes the capacity of the battery to decrease. Any flow whose direction is away from the positive terminals of the battery and into the negative.

Distribution Panel.—See *Panel, Distribution.*

Double Contact.—A name descriptive of a lamp bulb whose base carries two metallic points through which current enters and leaves the bulb. Also applied to a base designed to receive such a bulb.

Double Deck.—A motor and a dynamo which form separate units electrically but which are mechanically fastened together with one above the other either in one housing or in separate cases.

Double Wire.—See *Two-Wire System.*

Dynamo.—An electric machine which changes mechanical power into electric current.

Ediswan.—See *Bayonet.*

Efficiency.—The amount of useful work or power that may be taken from a device in proportion to the power or work of some other form that is consumed by the device while working. The efficiency of a storage battery is the percentage of ampere-hours' discharge that may be secured in comparison with the number of ampere-hours' charge that is given. The efficiency of a dynamo is the percentage of current that it delivers in proportion to the power it requires to drive the dynamo while delivering that current. The efficiency of an electric motor is the percentage of power delivered in proportion to the flow and pressure of electricity that the motor requires in order to deliver that power.

Electricity.—The name given to the cause of electrical effects of all kinds.

Electromagnet.—A magnet made from a core of soft iron and magnetized by the passage of a current of electricity through a coil of wire surrounding the core.

Electromotive Force.—Electrical pressure, potential or voltage. Ability to do work.

Energize.—In speaking of a coil or magnet this means that the coil or magnet receives current and produces magnetism.

Faure Plate.—A pasted plate for a storage battery. See *Plate, Pasted.*

Field.—The space around the poles of a magnet through which the magnetism or magnetic lines of force of the magnet will produce certain effects is called the field of the magnet. As the word is ordinarily used it means the field winding or the field winding and magnet core of a dynamo or motor.

Filament.—The conductor carried inside of the bulb of a lamp and which gives light when heated to incandescence by the passage of current against its resistance and through its length.

Finish Rate.—The number of amperes that may safely be passed through a storage battery for a period of from eight to twenty-four hours in completely charging the cells. Same as twenty-four rate. Depends on the ampere-hour capacity of the battery and is usually a number of amperes that corresponds to about one-twentieth of the ampere-hour capacity.

Floating.—Placing a battery in a lighting and starting system so that one side of the circuit includes and attaches to the positive terminal of the battery, of the dynamo, of the lamps and of the starting motor, and so that the other side of the circuit attaches to the negative terminals of these units. The battery may then receive current from the dynamo when the dynamo output is above the current required by the lamps, etc., and will give the required additional amount of current to the circuit whenever the dynamo output is less than the requirements of the current-consuming devices. The battery acts as a reservoir into which any excess current passes and from which any deficiency may be drawn.

Foot Pound.—See *Pound, Foot.*

Formed.—The condition of storage battery plates after the material in their plates has been changed to peroxide of lead for the positive and to sponge lead for the negative by the passage of a charging current and by intervening

discharges sufficient in number and time to produce this effect.

Fuse.—A short length of wire of various compositions which is so proportioned and made that it will carry any amperage up to a certain predetermined maximum, but will heat to the melting point and separate when this current is exceeded, thus breaking the circuit protected by the fuse.

Fuse, Cartridge.—A fuse enclosed in a tube, generally made from fibre or glass and capped with metal at each end so that when placed in fuse clips the current may pass from the clips through the caps and through the fuse. Used when it is desired to avoid a spark in the open air.

Fuse, Field.—A fuse placed in the circuit of the field windings of a dynamo and of such a capacity that it will melt and open the field circuit when the amperage reaches a point beyond which there would be danger of burning out the field windings themselves.

Fuse, Link.—An unenclosed fuse wire.

Gap, Air.—The distance between the end or pole of a magnet and the iron of the magnet's armature which may be the iron of the dynamo or motor armature core or the armature piece of an electromagnet.

Gassing.—The evolution of hydrogen and oxygen gases from the water in the electrolyte of a storage cell caused by the passage of charging current through the cell.

Gear.—The larger one of two toothed wheels which are in mesh. The smaller one is called the pinion.

Gear, Helical.—A gear having its teeth of such form that they slant across the face. If such a gear were wide enough across the teeth or long enough in the direction of its hub and axis, the teeth would form complete turns around it.

Generator.—A name sometimes applied to a dynamo.

Gramme Ring Armature.—See *Armature, Ring.*

Gravity.—See *Specific Gravity.*

Grid.—The metallic framework which supports the active material and which with the active material forms a plate of a storage cell.

Ground.—The name applied to the metal parts of a car. The "ground" or metal is used to complete one side of

the circuits in a one-wire system. Whenever a conductor or an electrical device is in metallic and electrical connection with the metal parts of the car the conductor or device is said to be "grounded" to the part on which it attaches or is mounted. See also, Circuit, Grounded and Circuit, Short.

Ground Return.—A name applied to a one-wire system or a system in which a part of either the positive or negative side of some or all of the circuits is completed through the metal work of the car.

Holder, Brush.—The part of a dynamo, motor, rheostat, etc., to which the brushes are fastened or in which the brushes are carried. The holder may be rigidly mounted or may be carried on pivot bearings.

Horsepower.—The rate at which work is done when 33,000 pounds is raised to a height of one foot in one minute. Provided this amount of work has been done in one minute one horsepower is being expended. To do the same amount of work in one-half the time would require twice the mechanical power or two horsepower of effort although the total amount of work done would remain the same. An electrical horsepower equals 746 watts. The horsepower that a current is capable of developing may be found by multiplying the number of volts by the number of amperes to find the number of watts and then by dividing this number of watts by 746, which will give the number of horsepower or the fraction of one horsepower.

Hydrometer.—A device for finding the weight of a liquid in relation to the weight of water. The usual form of hydrometer consists of a glass tube weighted at the lower end, having an air bulb above the weight and carrying a thin extension or tube above the air bulb. The hydrometer will sink into any liquid to a point on the extended tube or stem that corresponds to the weight of that liquid. The stem is graduated according to the specific gravity scale which assumes water to be unity and represented by 1.000. A liquid twice as heavy as water would then have a specific gravity of 2.000, etc. The point on the scale carried by the stem to which the hydrometer sinks indicates the weight or specific gravity of the liquid in which it is floating. See *Specific Gravity.*

Hydrometer Syringe.—A glass tube containing a hydrometer and into which a liquid to be tested may be drawn through a nozzle at the lower end of the tube. The upper end of the tube carries a rubber bulb which may be compressed to afford the suction necessary in drawing liquid into the tube.

Ignition-Dynamo.—A dynamo which carries an ignition breaker and distributor driven from the dynamo shaft and designed to make use of current from the dynamo or the storage battery charged from the dynamo.

Indicator.—A device which indicates flow of current through a circuit in which it is placed and shows in which direction the current is traveling. Some indicators have a hand like an ammeter, this hand swinging to words such as "Charge" when the battery is receiving current, "Off" when there is no flow into or out of the battery, and "Discharge" when current flows from the battery. In some forms the words themselves move into view according to the conditions existing. These instruments are often called "C. O. D. Indicators."

Induction.—The production of electrical pressure in conductors which are moved into and out of a magnetic field or which are allowed to remain stationary while a magnetic field in which they lie alternately increases and decreases. Induction is brought about when conductors move through lines of force or when lines of force move across a conductor. The current that is caused to flow in the conductor by the pressure is often called an induced current.

Inertia Pinion.—A starting motor drive operating on the same principle as the Bendix Drive, which see.

Inherent.—Some effect in a machine that is a natural result of the design and construction used in the machine and that does not require the use of external or additional moving parts to accomplish the result. Used to describe certain forms of regulation, especially reversed series systems in which it is the direction of winding the series coil that produces the inherent regulation.

Insulated Return.—A name applied to a one-wire system, which see.

Insulation.—Material that is a non-conductor of electricity and that is used in connection with conductors to prevent

current passing from the conductor at any point where such passage is not desired.

Iron Wire Control.—A system of regulation used with Rushmore and some Bosch-Rushmore dynamos by which a length of iron wire is made to send current through a bucking field coil by the heating of the iron with passage of excessive current through it.

Jar, Battery.—A receptacle made from a material that will carry liquids without leakage and which is an electrical insulator. The plates and electrolyte of storage cells are placed in the jar.

Junction.—A terminal connection, often enclosed, at which a circuit divides into two or more parts.

Keeper, Magnet.—A small piece of iron or steel placed across the poles or ends of a permanent magnet and affording a path through which the magnetic circuit may be completed.

Kilowatt.—One thousand watts. Approximately 1⅓ horsepower.

Lead, Peroxide of.—The chemical substance formed by the combination of one part of metallic lead with two parts of oxygen.

Lead, Sponge.—Pure metallic lead of a porous or spongy form.

Lead, Sulphate of.—The chemical substance formed by the combination of one part of metallic lead with one part of sulphur and four parts of oxygen.

Lines of Force.—The paths taken by the magnetism around the poles and in the fields of magnets.

Load.—The resistance placed in a circuit and through which current passing in that circuit must flow. The load may take the form of lamps, starting motor or any other current-consuming device.

Magnet.—A material possessing the power of attracting other magnetic bodies or iron and steel. A material having a field of magnetic lines of force. For practical purposes magnets may be made only from iron or steel.

Magnet, Compound.—Two or more single magnets placed together so that their like poles are side by side.

Magnet, Electro.—See *Electromagnet*.

Magnet, Permanent.—A magnet made from hard steel and which remains magnetic for long periods of time under ordinary conditions of use.

Magnetic Lines of Force.—See *Lines of Force.*

Magnetism.—The condition of a magnetic material or a coil when they are surrounded by a field of magnetic lines of force.

Magnetism, Residual.—A slight magnetism that remains in any piece of iron or steel after it has been once magnetized.

Manual Cut-out.—See *Cut-out, Hand or Manual.*

Marker Bulb.—A small bulb carried by one of the large lamps of a car but outside of the focal point of the reflector. Also called pilot or dimmer bulbs.

Material, Active.—The paste formed from compounds of lead mixed with dilute sulphuric acid which is used to fill the grids of storage cells in making plates.

Mercury Well.—A voltage regulator used with some types of Delco equipment in which a resistance in the field circuit is more or less short-circuited by a bath of mercury.

Meter, Ampere-Hour.—A device that measures and indicates the quantity of electric current passing into or out of the storage battery. Used in connection with the regulating system of some Delco equipments.

Miniature.—The smallest size of screw base for incandescent lamps.

Motor.—An electric machine that changes electric current into mechanical power.

Motor-Dynamo.—An electric machine having one armature core with either one or two windings; one or two commutators and one set of field cores with two or more windings, which acts either as a dynamo or motor, according to whether it is supplied with power or electric current.

Multiple.—A form of circuit in which two or more sources of current or two or more current-consuming devices have their positive terminals connected together and their negatives connected together.

Negative.—See *Polarity.*

Neutral Wire.—A wire connected to each of two sources of current, either batteries or dynamos, so that current may flow in either direction through the wire according

to which one of the two sources is being drawn upon for the greater amount of current. When the load is evenly divided between each source the neutral wire carries no current.

Nitrogen Bulb.—An incandescent lamp bulb in which the air has been replaced by the gas nitrogen.

Ohm.—The unit of the resistance to the passage of electricity. An ohm is the resistance that will allow one ampere of current to flow in a circuit when the pressure is one volt.

Ohm's Law.—The relation between electrical pressure, current flow and resistance is expressed by Ohm's Law as follows: The current or amperage equals the voltage divided by the resistance in ohms; the voltage equals the amperes of current multiplied by the resistance in ohms; the resistance may be found in ohms by dividing the voltage by the current in amperes. When *C* represents amperes, *E* represents volts and *R* represents ohms, the law may be expressed by the equations:

$$C = \frac{E}{R} \qquad E = C \times R \qquad R = \frac{E}{C}$$

One-Unit System.—An electric starting, lighting and ignition installation in which an ignition breaker and distributor is combined with a motor-dynamo thus allowing one unit to perform the three functions of lighting, starting and ignition.

One-Wire System.—A method of connection in which one side, either positive or negative, of all or part of the electrical devices and conductors is attached to the metal or ground of the car and in which the metal is used as a conductor to complete these circuits.

Open.—See *Circuit, Open.*

Output.—The number of amperes or the number of watts furnished by an electrical source such as a dynamo or battery.

Overrunning Clutch.—See *Clutch, Overrunning.*

Panel, Distribution.—A body or plate of insulating material to which lead the conductors for several circuits and

which carries suitable terminal connections and suitable internal and external wiring to allow the circuits to be completed in their proper paths. Used to centralize the wiring and connections of the electrical system.

Parabolic Reflector.—A reflector whose surface is so shaped that a section cutting from side to side and through the center would form a parabola. This form causes the light reflected from a source of illumination placed in the fucus of the parabola to be thrown in parallel rays and straight ahead in the direction of the axis of the parabola.

Parallel.—See *Multiple.*

Paste, Battery Plate.—The filling for the grids of storage cell plates. See *Material, Active.*

Peroxide of Lead.—See *Lead, Peroxide of.*

Pig-Tail.—A short flexible wire that forms the electrical connection between a brush and the conductor that carries current to or from the brush.

Pilot Lamp.—A lamp placed in a charging circuit in such a way that it lights when the cut-out closes and remains lighted while the cut-out remains closed. Also used to designate a Marker Bulb, which see.

Pinion.—The smaller of two toothed wheels which are in mesh. The larger one is called the gear.

Plate, Battery.—One of the units entering into a storage battery cell. The plate is formed of a metal framework or grid whose spaces are filled with active material formed from a paste of compounds of lead mixed with dilute sulphuric acid. After forming, the material of the positive plate is peroxide of lead and that of the negative plate is sponge lead.

Plate, Pasted.—A plate conforming to the foregoing definition of Battery Plate as distinguished from plates formed from pure metallic lead which has been acted upon by the passage of charging current to change the surfaces into peroxide of lead and sponge lead for the positive and negative respectively. Sometimes called a Faure plate from the name of its inventor.

Plug, Vent.—A small screw or clamping plug placed in the opening of each cell of a battery and by means of openings in which the gases evolved during charging may escape.

Point.—One-thousandth of a specific gravity unit or 0.001. The difference between a specific gravity of 1.251 and 1.252 is one point, between 1.250 and 1.275 is twenty-five points, etc.

Polarity.—The direction in which electrical pressure tends to cause movement of a current determines the polarity. It is assumed that the earth forms a reservoir of electricity which does not tend to flow. When current flows to the earth the polarity of the conductor through which it passes and the earth end of the conductor is said to be positive. When current flows from the earth to a conductor and through the conductor the end of the conductor at which the current enters and the conductor itself is said to be of negative polarity. Current having positive polarity will flow in one direction and will pass to a conductor of negative polarity, while current from a negative conductor will not flow to one of positive polarity.

Should a positive conductor having a pressure of eight volts be attached to the end of another positive having a pressure of only six volts, the first will be positive to the second while the second, which was called positive, will become negative to the first conductor. Had the conductor with six volts pressure been connected to another having only four volts, the six-volt line would be positive to the four-volt, and the four-volt line would become negative to the six-volt. In this case the conductor having the higher voltage or pressure will be positive while the one of lower voltage will be negative.

In the case of a source of electricity, the terminal or end from which current is supposed to flow is called the positive terminal, while the terminal into which current flows is called the negative. Current flow is always from positive to negative and from a higher voltage to a lower.

Wires attached to a positive terminal are called positive wires until they reach the current-consuming device or the outer end of the circuit. Wires from the consuming-device to the source and attaching to the negative terminal at the source are called negative wires.

Magnetic polarity is used to distinguish the ends or poles of a magnet and is determined according to the direction of movement of the magnetic lines of force. The pole

from which the lines of force leave the body of the magnet is called the positive or North pole and is designated by a plus sign, +. The pole at which the lines of force reenter the body of the magnet is called the negative or South pole and is designated by the minus sign, —.

Pole, Dynamo or Motor.—The ends of the field magnet cores that are presented to the armature and which form the walls of the armature tunnel. An electric machine having two field magnet cores is called a two-pole machine, one with four magnet cores or fields is called a four-pole machine, and so on, for any number.

Pole, Consequent.—A magnet pole formed when two ends of the same polarity, either positive or negative, are placed together, or a pole formed when two windings act to produce like poles at some point in a piece of iron located between the windings. In the case of a dynamo or motor the iron at the consequent pole is shaped to form a part of the armature tunnel but carries no windings.

Pole Piece.—A piece of iron or mild steel fastened to the end of a field magnet core and so shaped on its armature side as to form the curve of the armature tunnel.

Positive.—See *Polarity.*

Potential.—A term having the same meaning as voltage or electromotive force. The difference of electrical pressure between two points is their difference in potential. Potential is measured in volts.

Pound, Foot.—The work required to raise a weight of one pound to a height of one foot.

Pressure, Electrical.—The force that acts to send current through a circuit against the resistance of the circuit. Also called Potential and Electromotive Force. Measured in Volts.

Primary.—The winding of a transformer or ignition coil that receives the current from the battery or dynamo at low voltage and through the action of which on a magnetic core is produced the current of high voltage used for ignition. The wiring of the ignition circuits through which current of low voltage passes is called the primary wiring. A primary cell or battery is one which produces electric current by chemical action and in which this action can not be reversed as it can be in the storage cell.

Rectifier.—A device which changes an alternating current to a direct current.

Regulation.—The action of limiting or controlling the amperage, or voltage, or both amperage and voltage, of a dynamo.

Relay.—A device which closes or opens a circuit when the voltage or amperage rises to a certain value in a second circuit. A relay consists of an electromagnet through whose windings flows the current that controls the action of the relay and the time at which it will close a circuit, or open a circuit depending on its construction. When the relay is designed to close a circuit the armature of its magnet brings a movable contact to a stationary one and the circuit to be closed is completed through these contacts. When the relay is designed to open a circuit the movable and stationary contacts are so placed in relation to each other that movement of the relay magnet armature draws the contacts apart and opens a circuit that has been completed through the contacts. The word relay is often used to designate a cut-out or a regulator when these devices are electromagnetically operated.

Reversed Series.—A series winding placed on the field magnets of a dynamo and through which all of the current flowing from the dynamo passes in such a direction that the magnetic effect produced opposes the effect of the shunt field winding.

Rheostat.—A resistance or a number of resistances in series with each other whose effect in a circuit may be readily varied by changing the length or proportion of the resistance inserted in the circuit.

Section, Battery.—A part of a complete battery consisting of a number of cells arranged permanently in series with each other and having one positive and one negative terminal through which the section or series of cells may be connected with the outside circuits or with other sections of the battery in either a series or multiple circuit.

Segment.—A contact piece against which the brush of a motor, a dynamo or a rheostat bears and to which is attached one or more wires from the windings or resistances of these units.

Separator.—A sheet of insulating material, usually formed from specially prepared wood or hard rubber, which is used between adjoining plates in a storage cell so that these plates may not come into electrical connection with each other except at their lugs.

Series.—A connection of conductors made between several sources of current or between several current consuming devices in such a way that all of the current that passes through any one unit or conductor will also have to pass through every other unit and conductor in the series circuit. In the case of units having terminals of definite polarity the positive of one will be connected with the negative of the next one in the circuit and the positive of this second unit with the negative of the third, etc. See also Winding, Series.

S. G.—An abbreviation for *Specific Gravity,* which see.

Short.—See *Circuit, Short.*

Shunt.—A path of a circuit through which only a part of the whole current flows, the balance passing through one or more additional paths whose ends attach to the same source. When two conductors or two current-carrying devices are attached to a source of current so that there is a direct metallic path from each conductor or each device to each terminal, positive and negative, of the source, each part is called a shunt of the other one and the circuit from the source through either path and back to the source is said to be a shunt circuit. Any circuit in which part of the current may take one path while other parts take other paths consists of or contains shunts. Mutiple and parallel connections are forms of shunt circuits. See also *Winding, Shunt.*

Single-Contact.—A name descriptive of a lamp bulb whose base carries but one metallic point through which current may enter or leave the filament, the other side of the circuit being completed through the shell of the base. Also applied to a lamp base designed to receive such a bulb.

Single-Unit System.—See *One-Unit System.*

Single-Wire System.—See *One-Wire System.*

Solenoid.—A coil of wire without a metallic core, but through which a current may pass and which will produce

magnetic effects and a magnetic field when a current does pass.

Specific Gravity.—A measure of the weight of a liquid which is expressed in decimal fractions or multiples of the weight of an equal volume of pure water. The specific gravity of water is assumed as unity or 1.000. Any liquid one-half as heavy as water will then have a specific gravity of 0.500, while a liquid twice as heavy will have a specific gravity of 2.000 and one, one and one-half times as heavy will have a specific gravity of 1.500. See also Hydrometer.

Speed, Critical.—The speed of a car in miles per hour, of a dynamo armature in revolutions per minute, etc., at which some certain action will take place in some part of the electrical equipment. The speed at which a cut-out will open or close, at which a motor-dynamo will maintain a voltage equal to that of the battery without charge or discharge and at which a speed regulator will act are all critical speeds for those particular actions.

Sponge Lead.—See *Lead, Sponge.*

Start Rate.—In battery charging, the rate of flow or amperage which may be passed through the battery for the first hour of charge from a separate source, or the maximum rate that may be safely maintained by the dynamo on the car.

Stop Charge.—Descriptive of any device, such as a relay, that acts to open the field circuit or perform some other action that will result in stopping the flow of current from the dynamo.

Storage Battery.—See *Battery, Storage.*

Sulphate of Lead.—See *Lead, Sulphate of.*

Sulphated.—The condition of a storage battery plate when its surface has become covered with a thick formation of crystals of lead sulphate which prevent normal charge and discharge of the cells affected.

Sulphuric Acid.—The acid used in making storage battery electrolyte. It is composed of two parts of hydrogen, one of sulphur and four of oxygen and is a heavy oily liquid which will rapidly corrode and eat away most materials and will produce severe burns on the flesh. It has a specific gravity of 1.835 for the kind usually employed in battery work. For such use this acid must be chemically pure,

commercial acid not being suitable. Its action on the flesh or clothing may be stopped by the free and immediate application of strong ammonia water.

Switch, Commutating.—A form of switch connected to a battery composed of several sections and which places the sections in series with each other to produce a high voltage for starting while it connects them in multiple for charging and lighting.

Tandem.—A mechanical connection of two electric machines such as a dynamo and motor, a dynamo and magneto, etc., so that one shaft drives them both by passing through one unit and extending to the drive end of the other.

Tapering Charge.—A storage battery charge that decreases in amperage in direct proportion to the rise of voltage of the battery cells. A tapering charge is given by a dynamo whose voltage remains constant because the difference of voltage between dynamo and battery will be great at the beginning of the charge when the battery voltage is low, and will become less and less as the voltage of the battery more nearly approaches that of the dynamo as charging progresses.

Target.—A visible indicator or marker attached to the moving part of a cut-out or to the armature of a magnet whose winding forms part of the charging circuit. The marker will move into view when the cut-out closes or when current flows through the charging circuit.

Three-Unit System.—An electrical installation in which the starting motor, the dynamo and the ignition device are all separate and distinct units with no parts in common.

Three-Wire System.—A form of connection or circuit used for lighting with which two sets of lamps having different voltages may be operated from one battery or by means of which two sets of lamps are attached to two sections of a battery by means of three wires in place of four, the neutral wire acting for either set and being attached to both sections of the battery.

Third Brush.—A brush bearing on the commutator of a dynamo at a point somewhat distant from one of the main brushes and through which current flows to one end of the shunt field winding. The position of the third brush on the commutator determines the amount of current flowing

through the field and the voltage acting at this brush varies in such a way that a rise followed by a fall of voltage and current is obtained with constantly increasing armature speed. Forms a method of regulation.

Torque.—The rotative or twisting power exerted by a shaft.

Touring Switch.—A switch placed in the charging or field circuit or in both of these circuits so that when the switch is opened the charge to the battery will be stopped as may be desirable with a fully charged battery.

Transformer Coil.—A magnetic core around which are wound two separate coils having different lengths and sizes of wire in each coil. Passage of a current which is pulsating or alternating, or alternate flow and stoppage of a current through one of the coils will produce an induced current in the other. If the exciting or primary current flows through the coil having fewer turns the secondary current from the other coil will be of higher voltage and less amperage, while flow of the primary current through the coil having a larger number of turns will induce a current of lower voltage and greater amperage in the other coil.

Tunnel, Armature.—The cylindrical passage formed between the ends or pole pieces of the field magnets of a dynamo or motor and in which the armature is placed.

Twenty-four Hour Rate.—See *Finish Rate.*

Two-Unit System.—An electric starting, lighting and ignition installation in which two of the units are combined with each other, the third being entirely separate, thus forming two principal parts. Such a system may use a motor-dynamo with separate ignition device, or an ignition-dynamo with separate starting motor.

Two-Wire System.—An electrical installation in which both sides of all circuits are completed through insulated conductors and in which no part of any circuit is carried by the metal of the car.

Under Cut.—To cut away a part of the insulation between commutator segments so that the surface of the segments is above that of the insulation by about $\frac{1}{32}$ inch.

Vacuum Bulb.—An incandescent lamp bulb from which almost all of the air has been exhausted and has not been replaced with any other gas.

Vibrator.—An electromagnet together with its armature and contact points used as a part of a regulator and so designed and connected that the armature and movable contact point vibrate at a high rate of speed so that the circuit completed through the contacts is rapidly opened and closed.

Volt.—The unit of electrical pressure, potential or electromotive force. One volt pressure is produced in a conductor that cuts or is passed through by one hundred million lines of magnetic force per second. One volt pressure will cause a flow of one ampere through a circuit whose resistance is one ohm.

Voltage.—The electrical pressure existing between two points.

Voltage, Constant.—Descriptive of a form of regulation that allows the dynamo voltage at the dynamo terminals to rise to a predetermined maximum and then causes this voltage to be maintained without any great rise or fall at all higher speeds of the dynamo.

Voltammeter.—A single measuring instrument that may be used either as an ammeter or a voltmeter. Also an instrument consisting of a voltmeter and a separate ammeter in one case.

Voltmeter.—An instrument that measures difference in electrical pressure between two points and which indicates this difference directly in volts on a suitable scale.

Watt.—The unit of electrical power. The power delivered by a circuit through which one ampere flows at a pressure of one volt. The number of watts may be found by multiplying the number of volts by the number of amperes of a circuit. One watt is equal to 1/746th of a mechanical horsepower. One watt is the power that must be developed to do 44¼ foot-pounds of work per minute.

Watt-Hour.—A unit of electrical work equal to a power of one watt used or applied for one hour.

Winding.—A coil composed of one or a number of turns of a conductor around a magnetic core.

Winding, Compound.—A form of dynamo or motor field winding consisting of a shunt and a series winding wound on the same or separate magnet cores and acting on one armature.

Winding, Series.—In a dynamo or motor, a field winding through which passes all of the current that flows through the armature and brushes and in which the armature windings and field windings are in a series circuit with each other. In a cut-out, controller or regular magnet, the winding or part of the winding through which all of the charging current passes.

Winding, Shunt.—In a dynamo or motor-dynamo, a field winding placed in shunt with the armature windings and with the outside circuits and through which only a part of the current that is generated in the armature or that is received from an outside source will flow. The shunt field winding is made of much higher resistance than the outside circuits so that no more than the necessary amount of current required to magnetize the field magnets will pass through the winding. In a cut-out, controller or regulator magnet, the winding that is connected to the positive side of the dynamo at one end and to the negative terminal of the dynamo at its other end which is always acted upon by the difference in pressure or voltage between the dynamo brushes.

Zero Center.—Descriptive of an electrical measuring instrument such as a voltmeter or ammeter in which the indicating pointer may travel from the zero point toward either end of the scale, both sides being graduated and having the zero point at the center of the scale or nearer to one side than to the other so that a reading of greater value may be obtained with current flowing in one direction than with it flowing in the other. The latter class of instruments is not properly named "zero center" but should be designated by the maximum readings each way, thus "10-0-30" meaning an instrument that will read to ten amperes or volts one way and to thirty amperes or volts in the other direction.

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